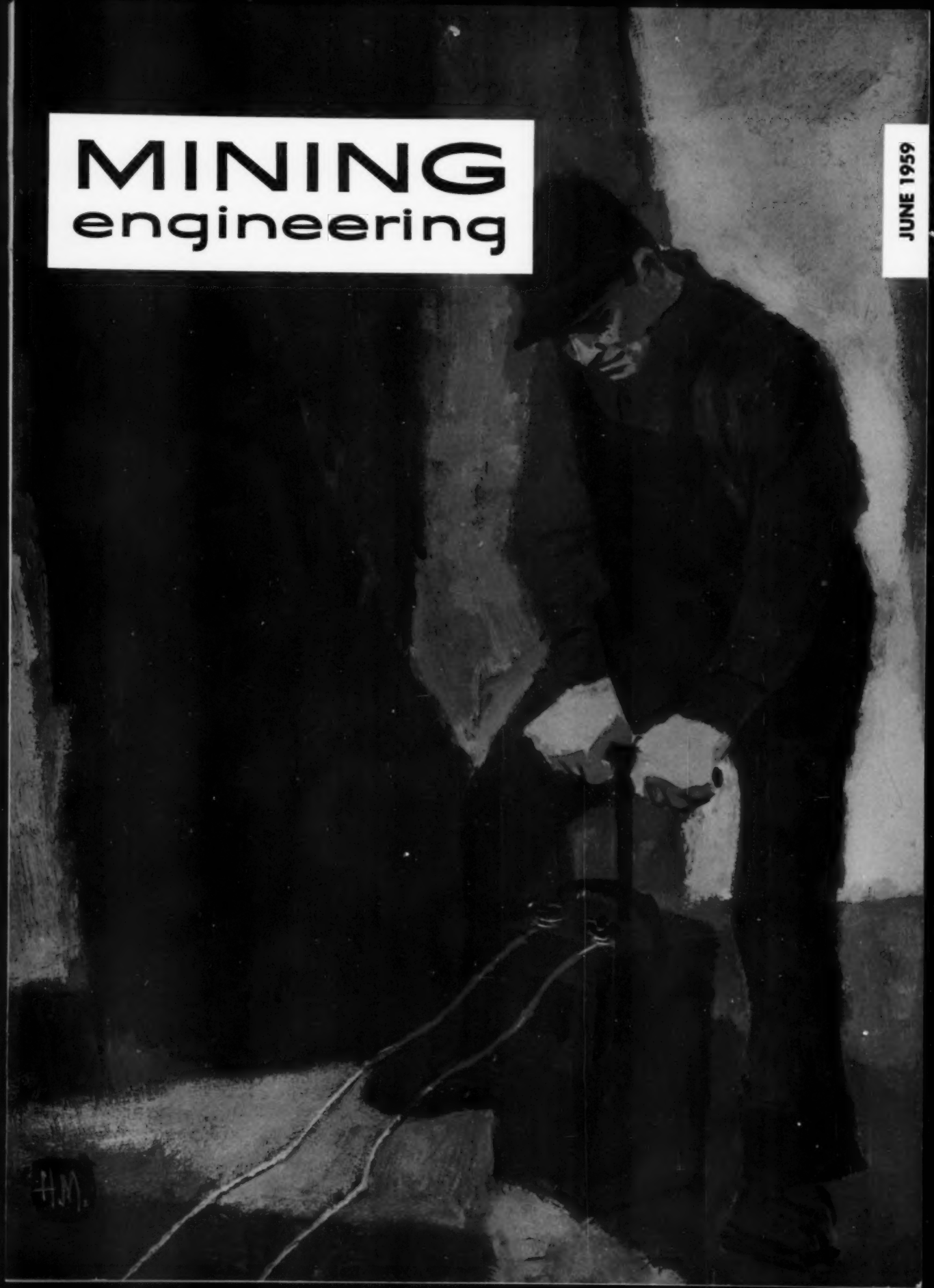
MINING engineering



JUNE 1959

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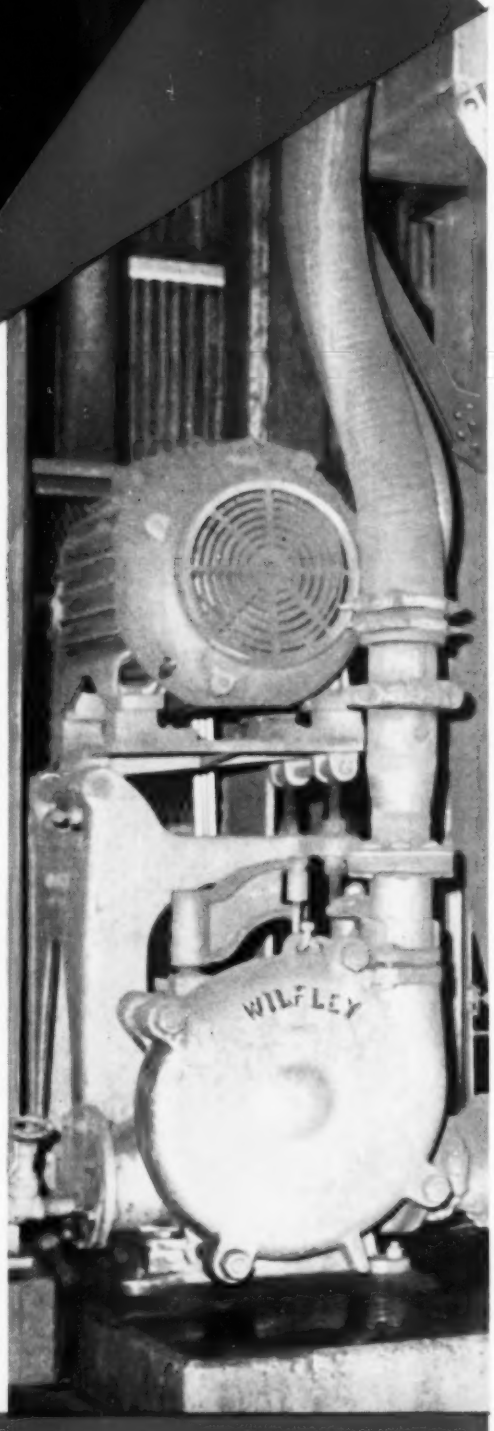
SAND PUMPS



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COMING EVENTS

June, AIME Lehigh Valley Section, field trip, New Jersey Zinc Co., Friedensville, Pa.

June 8-10, Engineering Inst. of Canada, annual meeting, Toronto.

June 10-13, National Soc. of Professional Engineers, annual meeting, Commodore Hotel, New York.

June 11-12, Southern Research Inst., "Undiscovered Earth" conference, Birmingham.

June 21-26, ASTM, annual meeting, Hotel Chalfonte-Haddon Hall, Atlantic City, N. J.

June 24, AIME Pennsylvania-Anthracite Section, annual summer meeting, Irem Temple Country Club, Dallas, Pa.

June 27, AIME Adirondack Section, field trip to Cabot Minerals Div., Willsboro, N. Y.

June 28-July 1, Rocky Mountain Coal Mining Inst., annual meeting, Antlers Hotel, Colorado Springs, Colo.

July 9-18, Mining Machinery Exhibition, Grand Hall, Olympia, London, England.

July 15-17, International Symposium on Shaft Sinking and Tunneling, sponsored by Inst. of Mining Engineers, Apex Conference Hall, Olympia, London, England.

July 25, AIME Adirondack Section, field trip to New York Seaway and Federal Power Authority, Massena, N. Y.

Aug. 10-17, annual conference, Autralasian Inst. of Mining and Metallurgy, Melbourne, Victoria, Australia.

Aug. 29, AIME Adirondack Section, field trip to Canadian Titanium Pigment Co., Varennes, Que., Canada; trip with wives, headquarters at Montreal.

Sept. 8, AIME Morenci Subsection, Arizona Section, Longfellow Inn, Morenci, Ariz.

Sept. 13-18, SME Minerals Beneficiation Division, American Chemical Soc. Colloid Chemistry Section, joint meeting on "Solid-Liquid Interphases," Atlantic City, N. J.

Sep. 14-17, American Mining Congress, Metal Mining & Industrial Minerals Convention, Denver.

Sept. 24-26, SME Industrial Minerals and Coal Divisions, joint meeting, Bedford Springs, Pa.

Sept. 26, AIME Adirondack Section, field trip to Ruberoid Co. asbestos operation, Hyde Park, Vt.

October, AIME Adirondack Section, field trip and football game, vicinity Syracuse, N. Y.

October, AIME Lehigh Valley Section, technical meeting.

Oct. 7-10, Rocky Mountain Assn. of Geologists, 11th annual field conference on Cretaceous sedimentary section in Colorado and adjacent areas; for further information, contact the association, Denver.

Oct. 8-10, Exploration Drilling Symposium, trisponsors: Colorado School of Mines, Pennsylvania State University, and University of Minnesota; Pennsylvania State University, University Park, Pa.

Oct. 12-14, 8th National Clay Conference, sponsored by Clay Minerals Committee, National Academy of Science—National Research Council, University of Oklahoma, Norman, Okla.

Oct. 27-29, 1959 AIME-ASME Joint Solid Fuels Conference, Netherland-Hilton Hotel, Cincinnati.

Nov. 9-12, Society of Exploration Geophysicists, annual meeting, Biltmore Hotel, Los Angeles.

Dec. 4, AIME Lehigh Valley Section, ladies' night.

Dec. 7, AIME Arizona Section, annual meeting, Tucson, Ariz.

Feb. 14-18,1960, AIME Annual Meeting, Hotel Statler, New York.

Feb. 16-19, Australasian Inst. of Mining and Metallurgy, Symposium on Hydrometallurgy, "Wet Processing of Minerals and Industrial Products," Adelaide, Australia.

MINING engineering

Vol. 11 NO. 6 **JUNE 1959**

COVER *Blasts are initiated as the plunger of the blasting machine goes down. Progress in blasting is initiated when we can put on paper what actually happens when explosives are fired. Turn to page 605 for a report on work with this end in view.*

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"Our Ford F-800's, pulling 20-ton payloads, give us mighty good service!"

says R. Dillard Teer, Vice President
Nello L. Teer Co., Durham, N. Carolina

"We operate about 115 Ford Trucks ranging in size from ½-ton pickups to Tilt Cab Tandem tractors. We believe in carefully fitting the truck to the job to be done and usually stay within the manufacturer's recommended ratings. We make an exception to this rule with our Ford F-800's, pulling 20-ton loads in aluminum trailer dumps to our quarry and crushing setup at Durham, North Carolina. These units are carrying the maximum legal limit and give us mighty good service!

"We haven't traded any trucks in about 6 years. It just happens that our company has been growing so rapidly that when we buy a new truck, usually an F-800, I put it under one of our trailer dumps. Then I'll take the old truck, lengthen the chassis, and make a grease outfit or a water wagon out of it. I would say out of over a hundred Ford units in the past 7 or 8 years, we have gotten rid of only a dozen altogether—and some of these were wrecked or burned.

"Another reason we use Fords is that this business is rough on trucks, so parts availability is very important. Our experience over the years with Ford as compared to Ford competitors has been definitely in favor of Ford on parts."

NOW! CERTIFIED PROOF!

FORD TRUCKS COST LESS

'59 Ford Pickups beat average mileage of other leading makes by 25.2% in Economy Showdown U.S.A.

Here at last is certified proof of the differences in gas mileage between six-cylinder pickups . . . evidence that you can use in your operation.

It was compiled by America's foremost independent automotive research firm after testing 1959 six-cylinder, ½-ton pickups of the six leading makes. All trucks were bought from dealers—just as you would.

The tests paralleled every kind of driving – high speeds and low, open highways and city traffic, even door-to-door delivery. And in every test, '59 Ford Sixes delivered more miles per gallon than any other make. Here are the actual percentages:

'59 FORD PICKUP SIXES GAVE

42.6% better mileage than make "D"
31.1% better mileage than make "I"
25.2% better mileage than make "C"
22.0% better mileage than make "S"
9.6% better mileage than make "G"

Taken together, Ford got 25.2% more miles per gallon than the average of all other leading pickups!

What's the secret of Ford's economy? First, of all pickup sixes, only the Ford Six has modern Short Stroke design which reduces friction and requires less fuel. Second, to this modern engine, Ford has added a new economy carburetor to meter fuel more precisely in both high- and low-speed ranges.

See your Ford Dealer for the full report of Economy Showdown U.S.A. and get the whole story firsthand.

All tests conducted and results
CERTIFIED
by America's foremost independent automotive research organization*
***NAME AVAILABLE ON REQUEST**
Send inquiry to P.O. Box 2687, Ford Division
Ford Motor Co., Detroit 31, Michigan

Now! During Dividend Days at your Ford Dealer's... Go *FORD*-ward for Savings

HEAVY-DUTY
HYDRASTROKE* FEEDER
FOR MINES and MILLS

A Reciprocating High-Tonnage Feeder easily adapted to feed Belts, Trucks, Skips, Railroad Cars, Screens and Crushers

Check these Outstanding Advantages

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Exclusive hydraulic power drive supplies the fluid to a cylinder which reciprocates the deck. Fixed or variable feeding rates are easily available through the use of a fixed or a variable volume pump. Length of stroke can be varied from 6 to 24 inches.

☐ **MINIMUM HEAD ROOM**

Head room requirements are reduced to as little as 20 inches. Impact damage is minimized because discharge lip of feeder is only 6 to 8 inches above lowest clearance line of feeder. Initial construction costs are reduced.

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May be installed with either rocker suspension or self-contained rocker mounted units. Eliminates costly wear due to friction which is present in other types of feeders. No lubrication is needed. Feeder can take severe shock loading.

Durability characterized by special rugged construction

Wide range of sizes available . . . widths from 36" to 96" . . . feeding capacities from 300 to 7500 tons per hour.

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Bulletin 07B7870 tells the complete *Superior* crusher story. Get a copy from your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin. In Canada, write Canadian Allis-Chalmers Ltd., Box 37, Montreal, Quebec.

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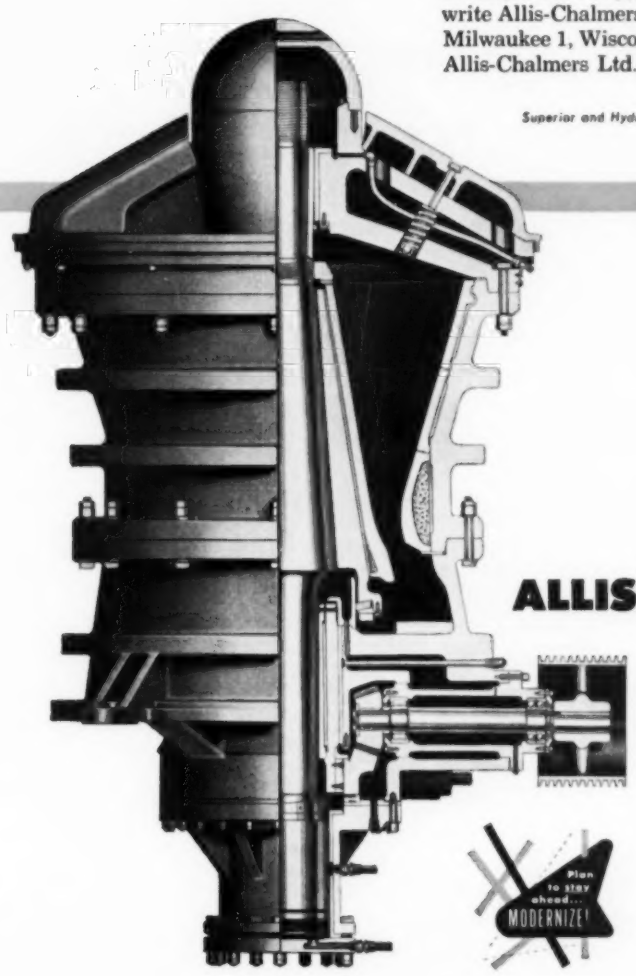

ALLIS-CHALMERS A-C

A-5933

PERSONNEL

THESE items are listings of the Engineering Societies Personnel Service Inc. This Service, which cooperates with the national societies of Civil; Electrical; Mechanical; Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and nonmembers, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5 pct of the first year's salary if a nonmember, or 4 pct if a member. Also, that you will agree to sign our placement fee agreement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number. When making application for a position, include 8¢ in stamps for forwarding application to the employer and for returning when possible. A weekly bulletin of engineering positions open is available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for nonmembers, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., New York 18; 57 Post St., San Fancisco; 84 E. Randolph St., Chicago 1.

MEN AVAILABLE

Mining Engineer, B.Sc., 39, single. Eleven years varied experience in base metals, fluorspar, iron and uranium. Experience covers mine engineering and production and mill supervision. M-480.

Geologist, B.S. in geology, age 32. Eight and one-half years experience exploration and evaluation of varied mineral deposits. Experienced planning and supervising all types of exploration programs. Good grasp of mineral economics. Seek position mining industry or related field with challenge and interesting potential. Location, immaterial. M-942-Chicago.

Mine Engineer, Chief of Party, Geology-Mining, Exploration, age 35, mining geology degree. Experienced geological engineer, mining reports on properties applying for production bonus; deputy chief, field administration of AEC uranium exploration program, reports, exploration results, ore reserves, geological reports, evaluation; as staff engineer, reported and evaluated organizations engaged in uranium mining and exploration; coordinated independent surveys for underground mining; assistant mine engineer, underground shrinkage-stope. Location, immaterial. M-1352-San Francisco.

Mine Engineer, Production, Sales Mining, Petroleum, Min.E. M.B.A., age 28. Experienced in mine planning, production estimates, mapping, exploration planning, layout, reserve estimates, survey crew supervision; large open pit iron mine. Location, immaterial but prefer West. M-1347-San Francisco.

Mining Engineer, Field Mining (Hard Rock, Non-Metallurgical), Construction, E.M. degree, age 25; two and one-half years as junior mine engineer, surveying, mapping, cost statistics, planning, efficiency studies, machinery design, contract payments, general engineering; uranium, potash. Location desired, southwest or west, M-1343-San Francisco.

Chief, Design, Mine Engineer, Resident Mining, Construction, mining engineering degree, age 28. Eight months as mine foreman, charge of above and underground shift, development, and construction; seven months as mine engineer, designing mine plant facilities, surface and underground survey, estimates, bills of material and construction measurement. Five months as engineer in training, mining. One year as draftsman, computor, layout and engineering of subdivision and roads, architectural and structural design. Two years USN, draftsman, public works. Location, immaterial. M-1366-San Francisco.

Geologist, Exploration Manager, A.B., M.S., age 40. Twenty years petroleum and mining exploration in U.S., South America, and Africa. Considerable experience in planning and directing large scale mineral explorations, and dealing with foreign governments. Prefer foreign location. M-481.

General Manager or Manager, E.M. degree, age 50. Twenty-five years varied mining experience, exploration, engineering, development, production, mostly underground; 14 years diversified management experience. Good nose for ore. Location, immaterial. M-1457-San Francisco.

POSITIONS OPEN

Photogeologist with experience in geological mapping to work in various reconnaissance projects. Training and experience in economic geology essential. Opportunity to inaugurate and supervise section of newly reorganized department. Considerable travel during summer months. Salary, open. Location, northwest. W7209.

Geologist for company manufacturing machinery. Location, Florida. W7152.

Mining Engineers, 2, recent graduates and one with possibly one or two years experience, to do surveying and mapping, etc. One applicant with chemical background would be useful. Salaries open depending on experience. Location, upstate New York. W6972.

Mine Superintendent, graduate mining engineer, with supervisory experience in underground metal mines, preferably with some experience in shrinkage stoping. Location, south. W7295.

Negotiating Engineer—Mining Contracts, preferably with solid mining and supervisory experience. Will be in charge of writing, measuring, and caclulating contracts with miners in a deep shaft operation producing 800 tpd of silver ore and other ores from a number of steeply sloped, relatively narrow veins. Salary commensurate with experience. Western U.S. S-4039.

Assistant Superintendent—Copper Mill. Must have good experience in mill operations and work with Spanish-speaking natives, Spanish necessary. For a large copper milling operation. Applications should be complete and by mail. Salary commensurate with experience. Transportation paid. Peru. S-4236a.

Metallurgist—Copper Milling, must be well qualified by experience and have proven ability to work with Spanish-speaking native workers, Spanish necessary. Submit applications by mail. Transportation paid. For a large, well established copper milling operation in Peru. Salary open. S-4236b.

Assistant Plant Engineer—Heavy Chemical, ME, ChE, or EM, up to 40 years of age. Past experience should include maintenance and operation of mineral extraction equipment, such as grinding, crushing, pulverizing, and thickening for chemical processing. Well qualified to assist in maintaining and modifying the equipment in an expanding heavy chemical plant of 40 to 50 people with 10 or 12 staff. Must have knowledge of chemical process equipment relating to corrosive acids, piping, pumping, and control of manufacturing. Salary to $600. San Francisco East Bay. S-4270.

Applied Research—Metallurgical Processes, M.S. or better with substantial chemical engineering background. Must be well trained in fundamental sciences and interested in solution of industrial problems. Will assist in applied research and development on improvements to new processes or major improvements in fields of beneficiation, hydrometallurgy, and pyrometallurgy. Salary commensurate with training and experience. Western U.S. S-4257.

Milling Manager (a), Mine Foreman (b), Mill Foreman and Metallurgist—Copper, Zinc Mining, and Milling, graduates or equivalent in experience. Must have good record and 5 to 10 years of experience in operating a medium sized underground mine and a two-circuit flotation mill. Salary commensurate with experience and ability. Arizona. S-4216.

Shooting for a fine break, 25,000 cubic yards of overburden were moved with fine fragmentation in this blast at a Bingham Canyon, Utah mine site. Nineteen 50-pound bags of Spencer N-IV Ammonium Nitrate were used in each of twelve holes, 63 feet deep—a total of 11,400 pounds of Spencer N-IV.

Record Rock-Moving Operation Uses New Spencer N-IV

No more trouble with leaking oil. Spencer N-IV is available in 50-lb. polyethylene plastic bags, so tough they reduce breakage as much as 50%. (Also available in 50, 80, and 100-lb. multiwall paper bags.)

Completely free-flowing, Spencer N-IV is used here at the rate of 0.5 pounds per cubic yard of rock in quartzite and from 0.8 to 0.9 pounds in limestone areas.

Efficient, low-cost ammonium nitrate gives greater blast energy on giant project:

Believed to be the biggest single rock-moving contract ever undertaken in the Utah area, Western Contracting Corporation's operation is set up to move 2,000 yards of overburden per hour! The job involves moving 8 million yards of quartzite and limestone overburden on the upper levels of the Bingham Canyon mine. By using Spencer N-IV Ammonium Nitrate, the contractor is able to speed up blasting, while keeping costs low. Made by Spencer Chemical Company, the uncoated N-IV produces more energy than commercial grade ammonium nitrates—yet costs no more!

No secondary blasting has been needed because Spencer N-IV gives such excellent fragmentation. Although the oversized equipment used on the job could easily handle large boulders, the contractor prefers a fine break to keep wear and tear on the machines to a minimum. Spencer N-IV produces its superior blast effect two ways:

(1) Spencer N-IV has a special structure which allows the prills to absorb oil more easily, and (2) Spencer N-IV contains a much higher percentage of ammonium nitrate than other brands. Another advantage of Spencer N-IV is that it reduces priming costs because it can be initiated with a single strand of 175-grain detonating cord. No need to attach additional material at intervals, and you put an end to the danger of storing high explosives on the job site!

For more information on new Spencer N-IV Ammonium Nitrate, write to Spencer Chemical Company, Industrial Chemicals Division, 403 Dwight Building, Kansas City 5, Mo.

AUCTION

COKE, GAS and CHEMICAL EQUIPMENT

of

CAMDEN COKE PLANT

Of The Public Service Electric & Gas Co.

Front & Chestnut Sts., Camden, N.J.

TO BE SOLD ON THE PREMISES—TO THE HIGHEST BIDDERS

TUESDAY, JUNE 23, 1959 AT 11 A.M. DST

The Public Service Electric & Gas Co. is ceasing the manufacture of coal gas at their Camden Coke Plant. All equipment used in this process is being liquidated. Certain coke processing and handling equipment is being retained until the disposal of the present stock of coke is completed.

American Pulverizer Ring Mill Crusher, type 38-S, 150/300 tons-per-hr. capacity. Penn Hammermill, size SXT-12, 125-tons-per-hr. Koppers Oven Charging Larry Cars, 10 ton capacity. Koppers Hydraulic Door Machines. Latimer Coal Spillage Bucket Elevator, 50 tons per hr., crushed coal Koppers Coke Oven Pusher 1947, 34′ C to C gauge, Atlas electric Coke Quenching Locomotive, standard gauge. Tippett & Wood Steel Sludge Settling Tanks, 42′ height. Steel Water Scrubbers 12′ diameter x 70′ height. Koppers steel inclined Drum Rotary Kiln, 4′ diameter x 30′ length. "Fluor Counter Flo" Cooling Tower 1954, Redwood with stainless steel fasteners. Koppers Elex Precipitator 8′5″ x 26′2″ height. Otis Elevator 118′6″ high travel, car size 2′10″ x 4′ x 7′4″ height. Complete Natural Gas-Air Jet Plant, 8 Schutte-Koerting Jets with rated capacity with 40-lb. gas; to produce 400 M-CFH, of 575 BTU gas. Five United Engineering Primary Coolers, 7′ diameter x 30′6″ height, Tar Decanter Separator 20′ x 46′ x 10′6″ deep, I-R Gas Compressors, duplex and compound types, I-R Turbo Exhausters 11,000-17,000 CFM capacity. Other Processing Equipment includes 2 Builders Coal Providence Proportioning and Weighing Equipment. Latimer Steel Bucket Elevator 15.2 tons-per-hr. Howe Larry Scale type 10-60. Koppers Hydraulic Door Machines, Koppers Steel Quenching Cars, Koppers and Barnes Coke Oven Gas-Air Reversing Mechanism. Hydraulic Door Jack. 2 Cottrell Gas Precipitators, Packaged Units designed to handle approx. 2 million cubic ft. coke oven gas per day. Patterson Hot Water Storage Heater, 500 gal. I-R, Elliott, and Alberger Barometric Condensers, 5,000/40,000 lbs. steam per hr. Sharples Sulphate Dehydrator Dryer Type C-20, 6 Andale After coolers, style 22 x A-12. Koppers Centrifugal Driers, 40″ basket. Hungerford & Terry Sand Filter, Research Engineering Mechanical Rectifiers, Koppers Ammonia Condenser, and Ammonia Still. Struther-Wells Heat Exchanger. United Filter Press, Sager Mud Mill, Lifting Magnets, and asstd. Rubber belt, steel Roller Conveyor Units, 13′11″ to 310′ long, 24″ to 42″ wide. Miscellaneous Plant Equipment includes: Terry 200 k. w. Steam Turbine, I-R single stage Air Compressors. Centrifugal, Reciprocating, Oil and Water Pumps, asstd. sizes. Large Steel Tanks, Recording Instruments, Generators, 956 New Cooler Tubes, 2″ diameter, 24′ long, #10 B-W gauge, C. I. Gas Valves 50 lb. and Machine Spare Parts. Rahn Larmon Gap Lathe, 24/48″ Swing x 6′ Gap, 16′ long. Landis heavy duty Pipe Threader 12″ capacity. Nat'l Bolt Threader, Cleveland Openside Planer 30″ x 8′ table, Nazel hydraulic Hammer size 4-D, Radial Drill, Toledo Hacksaw, Blount Grinder, Portable Electric Welders, small Bandsaw, Chain Falls, Pulley Blocks, Portable Electric Drills, Chipping and Scaling Hammers, Grease Gun Equipment, Space Unit Heaters, Fire Extinguishers, etc.

Exhibition: June 17, 18, 19 & 22 from 10 A.M. to 4 P.M. or by appointment

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LETTERS

A Mining Odyssey

Ed. Note: *We recently received this letter in answer to an invitation to Mr. Mitchell "to become a member." The names and places in his "odyssey" should bring back memories to many older SME members. With this experience as recommendation, it is the Society that would be honored by Mr. Mitchell's membership.*

Dear Sir:

I have from my early youth been "brought up on mining." My grandfather Capt. (Cornish honorary title) Abe Mitchell came to Bruce Mines, Ontario, Canada, with Lord Douglas as underground manager. My father learned mining under him and was active in mining all his life. In 1907 he went to the Transvaal as surface manager of Simmer en Jack. For the same company he was manager of the Rand Rud and Rhodes, the first deep level shafts on the Rand, then to general manager of the May Consolidated, a 100-5 ton stamp mill outcrop gold mine.

While he was on the May Consolidated I had two years of learner training—covering general mining (elementary mechanics of mining machinery, dam construction, assaying and mine surveying). We came back to U. S. during the Boer War. I attended Houghton, Mich., Mining School for one term. For the next several years I was diamond drilling and mining in Arizona and California. I returned to the Transvaal in 1904 and worked as shift man in a cyanide plant, diamond drilled, and mine foreman, and prospector for African Farms.

D. G. Bricker, a partner of my father's in the Burham (Old Stanhope) mine, went to Chile. I followed him down to Tierra del Fuego where I installed the machinery and developed a hydraulic gold mine. The bubble burst in Tierra del and I wandered up to Panama via East Coast, Amazon River, and over the hills and boat to get a job on the Canal as mine (open) foreman.

On the Canal I was foreman of construction. Diamond driller, general foreman of opening the sink holes and limestone caves on the ridge of Madden Dam, and research on procedure with F. H. Kellog, geologist, then in charge of injecting 3600 cu yd of clay slurry in the several saddles and dips of the soluble limestone stratum. In charge of field investigation on the third Locks Project. In charge of subaqueous mining as well as shore mining.

For different firms in Panama I built the precast dock at Porto Armuelles. The National Stadium in Panama City, the foundation investigation for El Panama Hotel in Panama City, and the grading and foundations for the cement plant in Panama.

I do not know who proposed my name, but I am grateful to him, for I have undoubtedly won his respect. I am sorry I cannot qualify for the high honor he would have had bestowed on me. I have done a lot of mining and have associated with many mining engineers and geologists. I can not but feel highly pleased that some one of my friends thinks enough of me to have sent in my name to a Society for which I have always had the highest respect.

In justice to my friend and that you should know I do not take this honor lightly, I thought the "Odyssey" of a mining tramp was due you both. Hope it has not been too prosaic.

Sincerely vours.

A. V. Mitchell
2863 Modesto Ave.
Oakland 19, Calif.

EIMCO

design and production

PROGRESS REPORT

B - 395

Process Engineers, Inc., division of The Eimco Corporation: 420 Peninsular Ave., San Mateo, Calif.

World's Largest Covered Thickeners in Operation At U. S. Borax & Chemical

Four 230 ft. dia. Eimco-Process heavy-duty thickeners have been in operation for over a year at the United States Borax and Chemical Corporation refinery in Boron, California. These totally enclosed and insulated thickeners, largest of their kind in the world, are part of the CCD circuit from which the strong Borax solution goes to crystallization.

The thickener designs, developed in close cooperation with Pacific Coast Borax Division personnel and the engineering constructors, are custom-adaptations of Eimco-Process Type CX mechanisms. The cover of each unit is supported from radial trusses receiving central support from an 8 ft. dia. concrete column with steel shell that also carries the entire weight and torque of the thickener mechanism. The drive-head with split main gear and bearing was designed to the specific requirement of providing easy maintenance access. A special liquid seal was devised to protect the drive unit from tank vapors, as well as to ensure close control of process conditions.

Four totally enclosed Eimco-Process thickeners at Boron, California

Other installation features were the resting of the steel thickener tanks on oiled sand for corrosion prevention; continuous torque recording; and handling the thickener underflows with steam driven reciprocating pumps.

This $20,000,000 processing plant, on an 80 acre desert site, was designed and constructed by Southwestern Engineering Company and Ford J. Twaits Company as a joint venture. It has substantially increased the U. S. Borax capacity and is playing an important part in the production of high energy boron fuels for the space age.

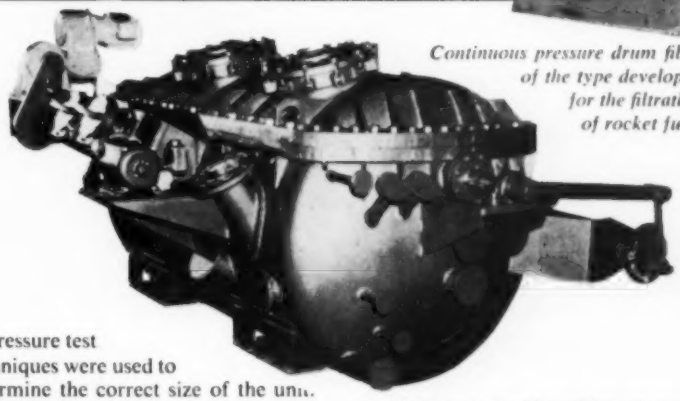
NEW BULLETIN AVAILABLE

We recently completed an eight page bulletin describing our thickeners, hydroseparators, air-lift agitators, reactor-thickeners, slurry mixers and related equipment. It also covers recent design innovations such as our unique Thixo arms and platform lifting devices, and should be in your reference library even if your immediate plans do not include thickening equipment. A request will bring one by return mail, or, if your plans *do* involve thickeners, our nearest sales engineer will deliver a copy in person.

Eimco Filtration Equipment Plays Important Role in Producing Rocket Fuels

At another plant, producing high energy fuels, engineers were faced with a troublesome filtration problem. They had to filter a fuel having an extremely low slurry viscosity, a high percentage of hydrogen in the gas, and containing a dangerously flammable material.

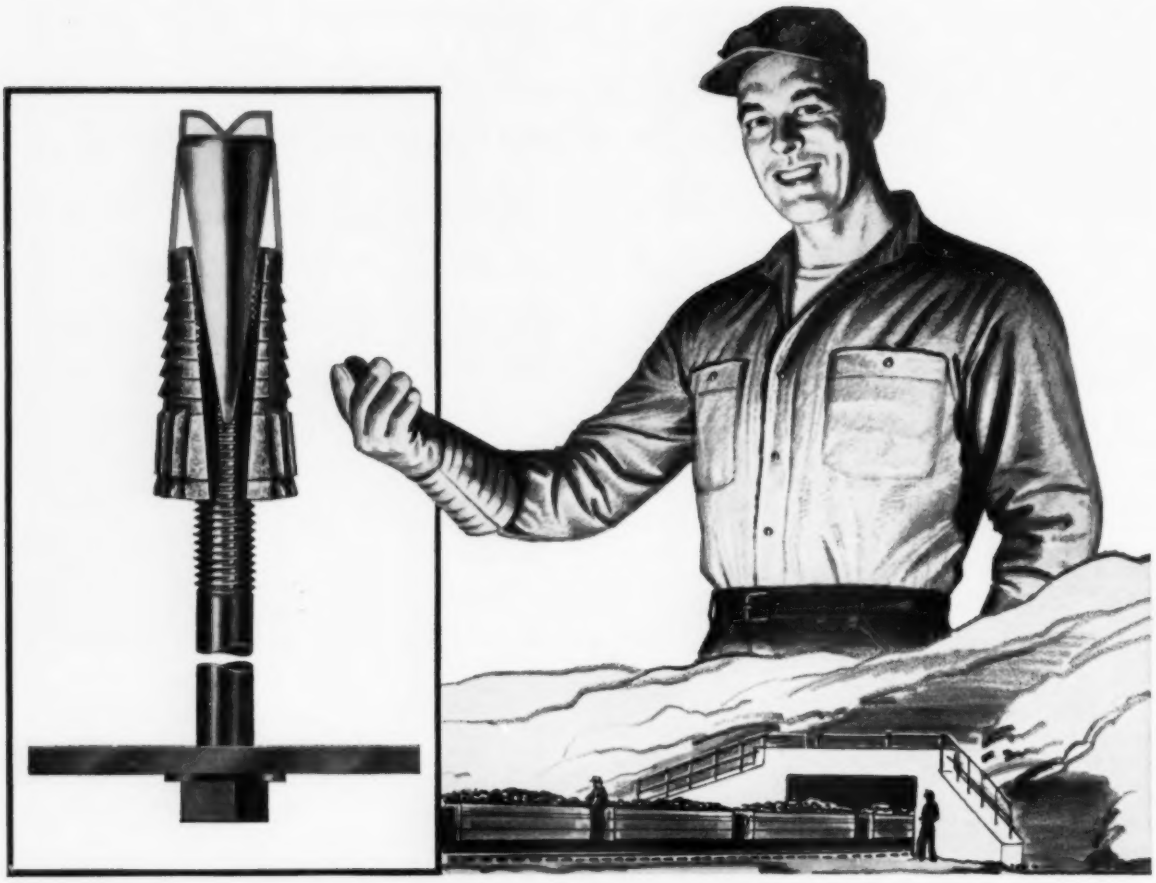
This problem was referred to Eimco's Research and Development center at Palatine, Illinois. Here, the Company's filtration research engineers, after a series of tests, were able to work out special adaptations for a continuous pressure drum filter that met all the specialized application requirements.



Continuous pressure drum filter of the type developed for the filtration of rocket fuels

Pressure test techniques were used to determine the correct size of the unit. Intricate seals were devised to keep air out of the pressure vessel. Changes were made in the hydraulic system. And, the filter was furnished with complete instrumentation.

This is typical of how Eimco's unexcelled research facilities and valuable backlog of experience in engineering custom-designed filter equipment can solve difficult filtration problems.



CF&I Rock Bolts with Pattin Shells give maximum anchorage

The Image of CF&I stands for a line of quality steel products that are prominent in the mining industry.

One of these—CF&I Expansion Rock Bolts with Pattin Shells—are widely used because of several exclusive design features. The double expansion of Pattin Shells gives parallel contact along the entire length of the hole, thus ensuring maximum anchorage in any type of rock. The Pattin design provides a maximum resistance to load with minimum displacement.

High strength steel—made to American Standard Specifications for roof bolting materials—provides an ample factor of safety. And CF&I Rock Bolts have been fully safety-tested, thoroughly proven in use.

Maximum utilization of available work space and ventilation facilities is possible with CF&I Rock Bolts, since cumbersome, space-consuming timbering methods are often unnecessary. When used with CF&I's Realock Metallic Fabric for lagging, CF&I Rock Bolts offer proved initial-cost savings up to 35% over timber set costs.

CF&I Rock Bolts with right hand threads are available in ¾″, ⅝″ and ⅞″ diameters, and in four different sizes of Pattin Shells. The ¾″ bolts are also made with left hand threads for tightening by drilling machines.

CF&I also makes a complete line of 1″ Wedge Type Rock Bolts, as well as ¾″ expansion type slusher pins.

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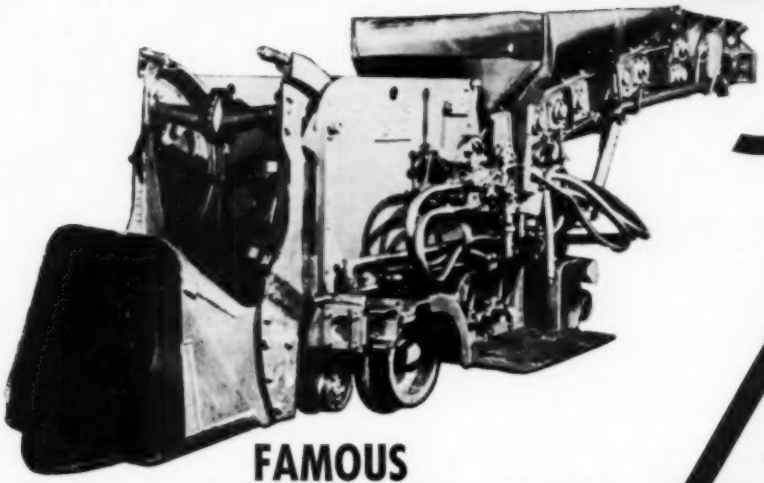

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BOOKS

Geology of the Great Lakes, by Jack L. Hough, *University of Illinois Press,* Urbana, Ill., 313 pp., $8.50, 1958—Descriptions of the present lakes and the processes operating in them start the book, with summaries of the events in the region that led to the formation of the earliest lakes. The second part includes a review of the literature on the lakes.

Minerals Yearbook 1957, Vol. II, Fuels, *U. S. Government Printing Office,* Superintendent of Documents, Washington 25, D. C., 488 pp., $2.25, 1959.

Minerals Yearbook 1957, Vol. III, Area Reports, *U. S. Government Printing Office,* Superintendent of Documents, Washington 25, D. C., 1252 pp., 1959.

Second Symposium on Coal Preparation, *Dept. of Mining, University of Leeds,* Coal Preparation Plant Assn., P.O. Box 121, 301 Glossop Road, Sheffield 10, England, 530 pp., $2.80 approx. (20s.), 1958—Proceedings of the symposium held Oct. 21 to 25, 1957, including 18 papers, discussion, special addresses and summaries, are covered in this volume.

The Life and Death of a Quicksilver Mine, by Helen Rocca Goss, *Historical Soc. of Southern California,* 1909 South Western Ave., Los Angeles 18, Calif., 164 pp., $5, 1958—The little-known story of the most important and longest producing California quicksilver mine rivals the tales of the Forty-niners. This book combines the lively history of the adventurous and competitive mining of cinnabar with the problems and methods of mining camp life, back in the days of 1875.

Angular Relations of Lines and Planes with Applications to Geologic Problems, by Donald V. Higgs, *Wm. C. Brown Co.,* 135 S. Locust, Dubuque, Iowa, 52 pp, plastic overlays for plates, $2.75, 1959—This book is intended for the student majoring in geology. The stereographic net and spherical trigonometry are invaluable to the geologist who deals with angular relations between lines and planes. This book's purpose is to explain the basic elements required for an understanding of graphical and numerical solutions of geologic problems.

Comstock Mining and Miners, by Eliot Lord, *Howell-North Books,* 1050 Parker St., Berkeley, Calif., 600 pp., $8.50, 1959—First published 75 years ago, this book has never been surpassed as the history of the Comstock Lode of Virginia City, Nev. This new edition includes a fine collection of photographs of the mines and people involved, with drawings of the mining and metallurgical processes then in use.

Dendritic Crystallization, by D. D. Saratovkin, *Consultants Bureau Inc.* 227 W. 17th St., New York 11, N. Y., 130 pp., $6, 1959—This edition has been revised from the 1953 version with fresh material derived from observations under the stereoscopic microscope. The first section discusses general concepts of crystallization, distinguishing between genetic and structural types of crystals. The second section covers the ideas of D. K. Chernov, 19th-Century Russian metallurgist. Current views are then presented, and a review of all types.

Drainage and Use of Methane from Coal-Fields, Developments Since 1956, *The Organisation For European Economic Cooperation,* 1346 Connecticut Ave., N. W. Washington 6, D. C. 116 pp., $1, 1958—Experts from Western Germany, Belgium, France, the United Kingdom, and representatives from mining and gas industries of the Saar coal-field attended a meeting to consider progress in drainage and use of methane from coal-fields since their 1956 report. Their meeting on May 7, 1958, discussed reports of members who had visited European coal-fields in 1954. This book contains the reports and papers of the meeting.

Researches in Geochemistry, edited by Philip Hauge Abelson, *John Wiley & Sons, Inc.,* 511 pp., $11, 1959—This comprehensive survey is written by experts in their respective fields, containing reviews of the present status of research, the author's own recent contributions, and extensive bibliography. Nuclear geology, geochronology, chemical considerations, and views on the interior of the earth are a few areas covered.

ABSTRACTS

In This Issue: *The following abstracts of papers in this issue are reproduced for the convenience of members who wish to maintain a reference card file and for the use of librarians and abstracting services. At the end of each abstract is given the proper permanent reference to the paper for bibliography purposes.*

New Techniques For Old Mines by *Alfred G. Hoyl, Paul L. Goddard,* and *William R. Sirola*—New approaches, new techniques, new equipment hold hope for new life in old mining districts. Large diameter drillholes for ventilation, underground radio triangulation, hoist ropes with conductors for communications, suspended work cage raising, and circular steel ore passes are now being used to revive a promising area in the Front Range mineral belt of Colorado. **Ref.: MINING ENGINEERING, June 1959, p. 586.**

Shaft Sinking and Development Under Hot Water Conditions by *Donald L. Anderson*—Presence of hot water brought on by volcanic action nearby has severely complicated mining in the Limon gold mine in Nicaragua. Routine pumping problems have been multiplied and ventilation is a major problem. Enclosing rock is so hot that 20 pct of all power generated at the mine is consumed by forced ventilation. But hot water underground, however disagreeable and troublesome, may be handled and surmounted like any other difficulty if the estimated profit margin permits. **Ref.: MINING ENGINEERING, June 1959, p. 592.**

Ice Tunneling in Greenland by *John F. Abel, John F. Sulzbach,* and *Donald K. Walker*—Modern mining equipment has been found adaptable to a unique ice mining operation in northwestern Greenland. Part of research program on arctic survival by the military, the operation has met a series of new tunneling problems. Tools so far have ranged from black powder to continuous coal mining machines. **Ref.: MINING ENGINEERING, June 1959, p. 594.**

The Copper Province of the Southwest by *Harris A. Schmitt*—One of the great copper-producing areas of the world is comprised of five U.S. western states and northern Sonora, Mexico. The southwest province of this area, covering southern Arizona, southwest-

ern New Mexico, and northern Sonora, produces 55 pct of U. S. copper output and the equivalent of 15 pct of world production. In 1956 the area produced about 550,000 tons. **Ref.: MINING ENGINEERING, June 1959, p. 597.**

Extrusion-Agglomeration of Iron Fines by *Ira A. Stark*—Problem in agglomerating or briquetting ferrous fines? Try the continuous pugmill-extruder. Use the clay-working machinery in the metallurgical industry is by no means new. Extrusion-agglomeration as a basic operation in the non-ferrous field has a history of more than 50 years. This article advocates using technique in the ferrous field where it might serve a useful purpose in today's operations. **Ref.: MINING ENGINEERING, June 1959, p. 601.**

X-RAY Mineral Analysis Techniques by *Ralph E. Wood*—A survey of applications of X-ray fluorenscence analysis techniques to problems of exploration and mining. Emphasis is placed on rate, accuracy, and expense compared with conventional wet chemical methods. **Ref.: MINING ENGINEERING, June 1959, p. 602.**

Rock Breakage With Confined Concentrated Charges by *Wilbur I. Duvall* and *Thomas C. Atchison*—This paper describes instrumented blasting tests and presents experimental data on crater formation in four rock types using small charges in a drillhole which break to one free surface. The compressive strain pulses generated in the rock at the time of detonation of the charges have been recorded and measured. High-speed movies of crater tests have been taken which show the various phenomena that take place during the process of crater formation. From analysis of these data the primary cause of rock breakage in a crater test is shown to be the result of tensile stresses developed when the compressive stress pulse reflects from the free surface. **Ref.: (MINING ENGINEERING, June 1959) AIME Trans., 1959, vol. 214, p. 605.**

Effect of Pulp Depth and Initial Pulp Density in Batch Thickening by *A. M. Gaudin, M. C. Fuerstenau,* and *S. R. Mitchell* (TP 4806 B)—Discussion: It has generally been thought that in a settling column of pulp that is initially of uniform pulp density throughout its height, two zones form shortly after the start of the settling process. The lower zone was thought to consist of compacting sediment and the upper zone of relatively fast-settling flocs. It was believed that this upper zone did not change in pulp density from top to bottom, or in time, but merely in the extent of its vertical dimension.

Since the settling of the mud-line is so strongly dependent on the height of pulp initially placed in the batch thickener, it may well be suspected that the above ideas—while correct in respect to the existence of two zones and the time-and-position variability in pulp density of the lower zone—are incorrect in respect to the homogeneity of the upper zone.

This reasoning has led to the construction of a device for measuring pulp density continuously as a function of time and position and without disturbance. This device, the Transviewer, has already been described, and work with it is actively in progress. The phenomena described here explain why it is believed the Transviewer will serve a useful purpose in the development of thickening theory. **Ref.: (MINING ENGINEERING, June 1959) AIME Trans., 1959, vol. 214, p. 613.**

Solid Phosphor Core Scanner For Determining Radiation in Drill Core Samples by *W. W. Vaughn, R. H. Barnett,* and *E. E. Wilson* (TP 4802-I)—An instrument that scans a moving train of drill core for radioactivity has been constructed and tested. The instrument will accept drill core from 1 to 3 in. in diameter by way of a continuous conveyor belt and will provide a permanent record of radioactivity as a function of core length. Use of chemically assayed samples containing uranium in equilibrium with its decay products makes possible a calibration curve whereby the equivalent uranium content of an unknown sample may be determined. The counting chamber has essentially 3π geometry and is shielded by lead walls 2 in. thick. Four sodium iodide crystals 2 in. in diameter by 2 in. thick and 4 photomultiplier tubes are used as the detecting elements. Although the core scanner was designed primarily to measure radioactivity in a continuously moving train of drill core, it may be used with equal effectiveness when properly calibrated to analyze crushed sample material in cylindrical cardboard containers. The sensitivity of the instrument is such that a variation in equivalent uranium oxide content of 0.01 pct will give a corresponding change of 50 counts per second in the recorded counting rate. Semiquantitative results are achieved with sample material containing as little as 0.005 pct eU_3O_8. **Ref.: (MINING ENGINEERING, June 1959) AIME Trans., 1958, vol. 214, p. 617.**

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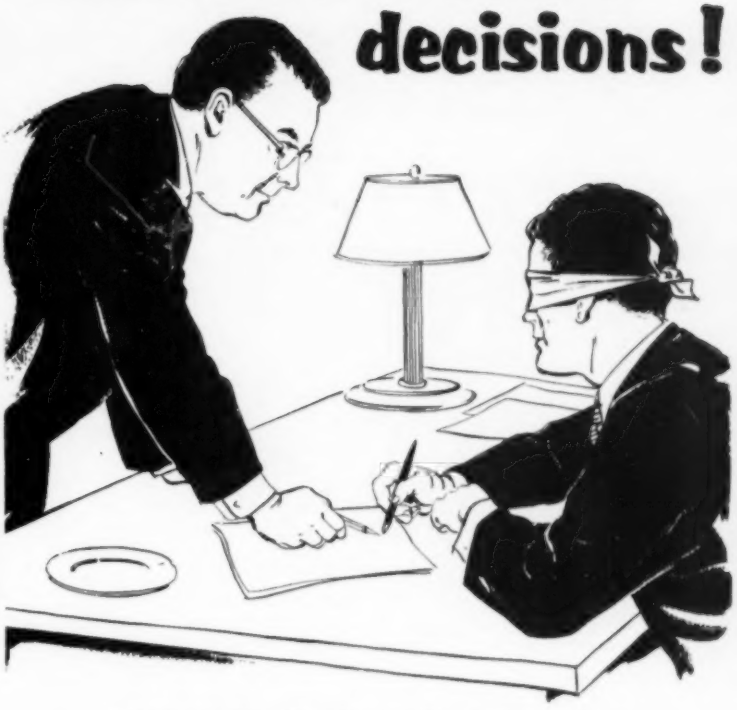

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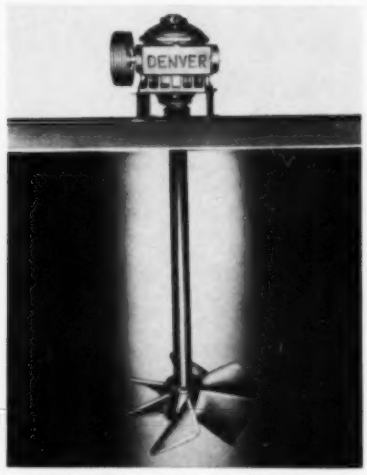

ers propellers up to 120-in. diam for tanks up to 50-ft diam by 40-ft deep. **Circle No. 1.**

Equipment Lease Plan

Nationwide Leasing Co. offers mining firms the opportunity of leasing equipment so that production facilities can be expanded and modernized without depletion of working capital. As an example, a $25,000 lease (all equipment is considered a single package) would cost $800 monthly for three years, $625 monthly for four years. Any combination of equipment may be lumped under one lease with one monthly payment. **Circle No. 2.**

Big Payloader

Highest dumping clearance, longest reach, and most powerful engine of any tractor-shovel of its size and capacity range—all are features of the new model H-120 Payloader by *Frank G. Hough Co.* Maximum height of raised bucket is 19

ft 2 in., Cummins diesel develops 300 hp, and recommended carrying capacity is 12,000 lb. **Circle No. 3.**

Fire Resistant Hydraulic Fluid

For improved mine safety *Shell Oil Co.* has introduced 3XF mine fluid, a water-in-oil emulsion with a built-in extinguisher which prevents fires when lines rupture. The fluid has been tested under working conditions for thousands of hours and was found noncorrosive and entirely compatible with normal systems. **Circle No. 4.**

Angling Bulldozer

Caterpillar Tractor Co. announces the No. 977A angling bulldozer is now available for the No. 977 Series E Traxcavator. Attachment adapts excavator for trench filling grading, and other bulldozer jobs. **Circle No. 5.**

Contour Filter Scraper

By folding or contouring to the bellows of a filter bag, a new scraper by *Peterson Filters & Eng. Co.* gives improved cake discharge, reduced bag costs, lower cake moisture, and greater capacity. Scraper is in three sections; rubber blade is held in tension against bag by plates which hinge independently of each other. **Circle No. 6.**

Froth Baffles

Dorr-Oliver Inc. has developed special froth baffles for its type S-120

thickeners installed at Homestake-New Mexico Partners' Grants, N. M., uranium mill. Baffles of 30-in. diam break up foam accumulation, and perimeter arrangement controls waves caused by high winds in the area. **Circle No. 7.**

Shuttle Car

National Mine Service Co. has introduced a new model TorKar shuttle car which will operate in extremely thin seams. The type 26 TorKar has over-all body height of 25½ in. and basic 110 cu ft capacity, which can be increased through use of sideboards. **Circle No. 8.**

Off-Road Haulers

Rugged simplified design is a feature of the new Haulpak line of haulers by *LeTourneau-Westinghouse Co.* Units ride on Hydrair suspension system, have almost twice

the front-end ground clearance of conventional trucks. Three models are available: 27-ton and 32-ton end dumps, and an 80-ton bottom dump. Exhaust-heated body is standard equipment. **Circle No. 9.**

Dustless Drill

A dry, dustless jack leg drill, which eliminates the need for water in drilling and also provides a continuous ore sample, has been developed by *Le Roi Div.*, Westinghouse Air Brake Co. Included is a dust collector tank which can be dumped by remote control from the drill. Cuttings pass out side of chuck housing, do not enter drill. **Circle No. 10.**

Portable Power Center

General Electric has custom designed a portable, skid-mounted station for distribution of a-c power in a coal mine. The 7200-v unit is just 42 in. high and includes newly designed cable couplers with contacts arranged to protect personnel. Relaying circuits are arranged to trip circuit breaker when overloads, short circuits, ground faults, interruption of ground continuity, or low voltage occur. **Circle No. 11.**

Shaft Jumbo

Machinery Center Inc. offers a 4-drill shaft jumbo intended to eliminate wasted set-up time, reduce driller's fatigue, drill perfect patterns. Jumbo can be lowered in its collapsed position through a 48-in. square shaft area and then placed on bottom by setting on pedestal type base. Spring and plunger locator allows drill arm positioning to drill wall and center holes in shaft bottom. **Circle No. 12.**

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Model AT50—"Air Trac" with hydraulic drill positioner and hydraulic remote controls.

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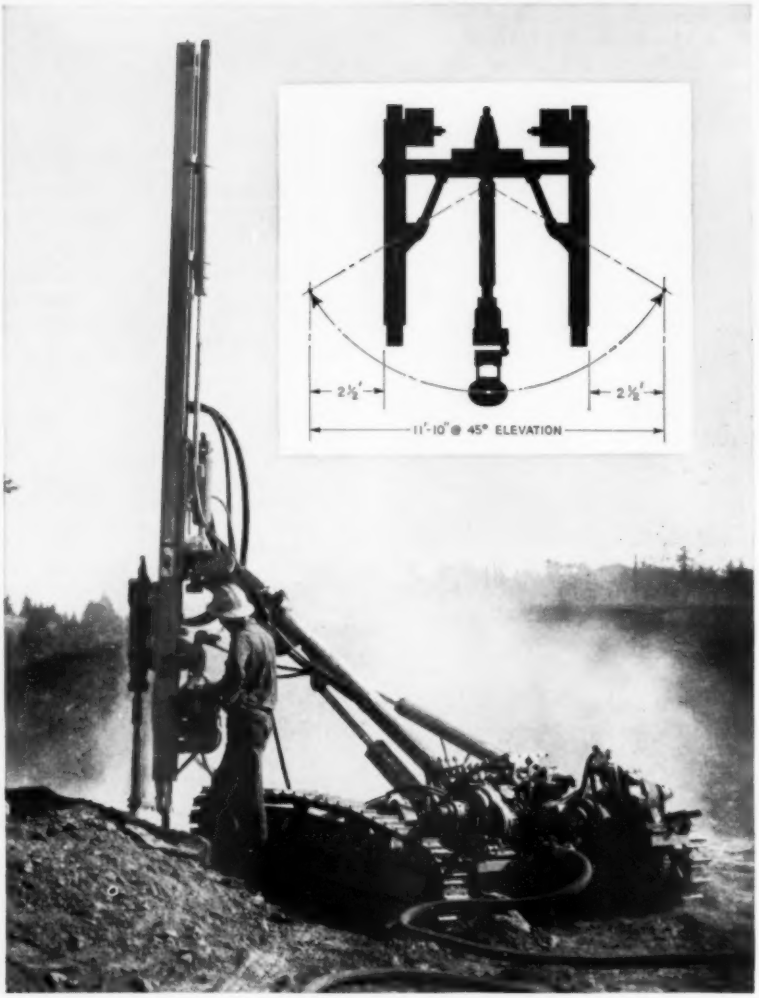
Model AT1500—like AT1000, has longer tracks and greater traction power. Designed for complete power positioning with hydraulic drill positioner and hydraulic remote controls.

Model HT-143—biggest and most powerful crawler drill available . . . carries the hard-hitting Gardner-Denver 5½″ drill.



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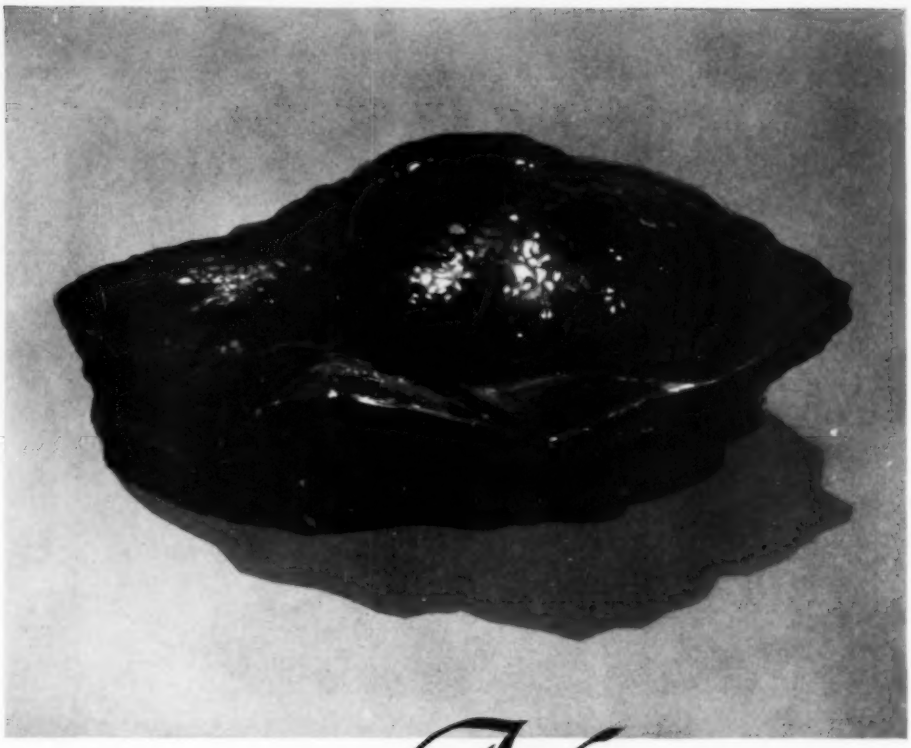

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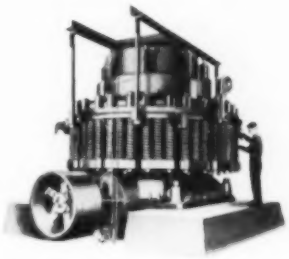

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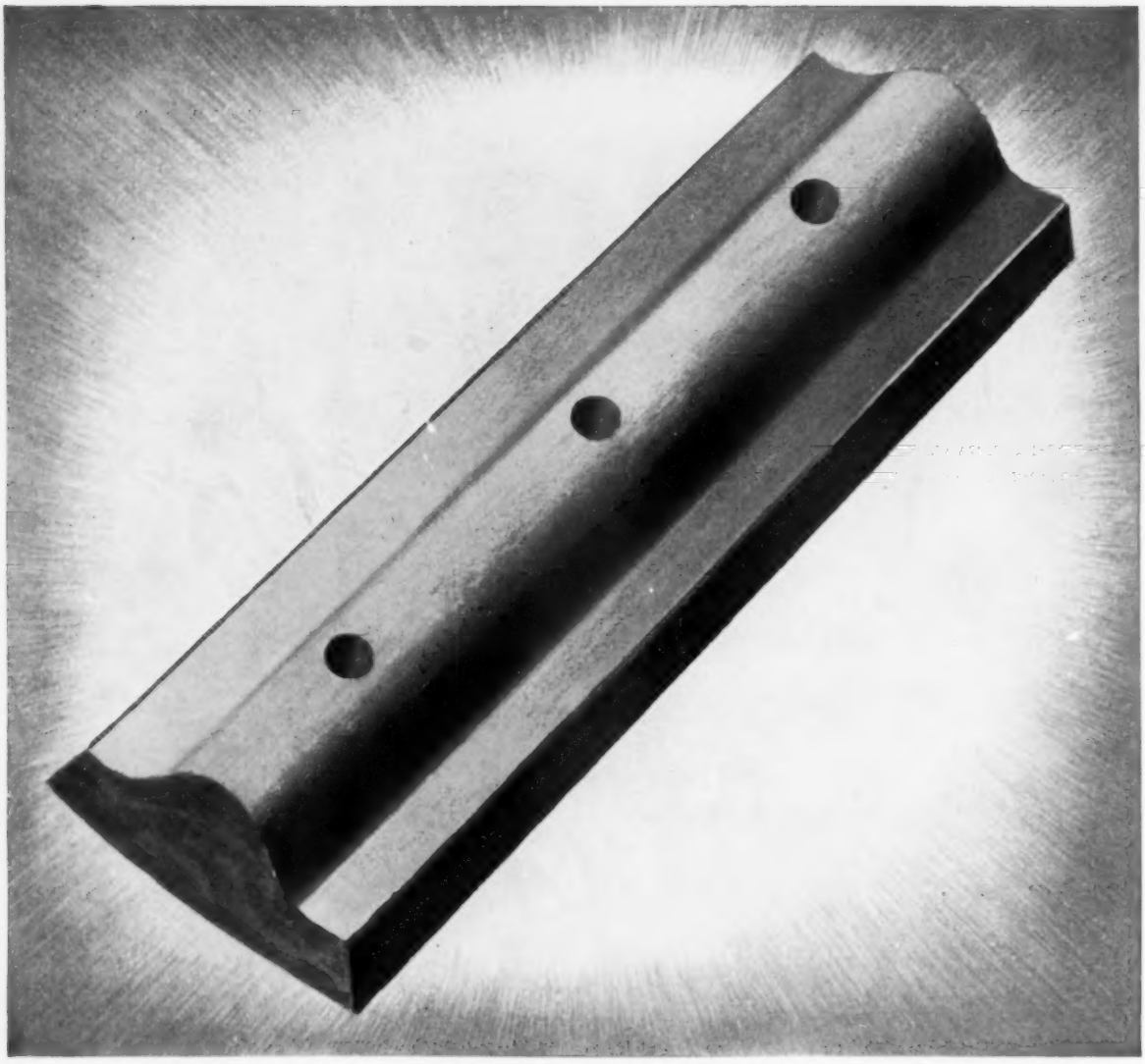

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Ni-Hard can mean important savings for you, too. Authorized producers throughout the country are ready to supply liner segments for your mills. Write Inco for the name and address of the one nearest you.

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NI-HARD

NICKEL MAKES CASTINGS PERFORM BETTER LONGER

Inco Nickel Refinery Planned

International Nickel Co. of Canada Ltd. has decided to construct an electrolytic nickel refinery at Thompson, Man., with a capacity of up to 75 million lb of nickel per year. This is the initially scheduled capacity of the Manitoba project. A main feature of the process is the direct electrolysis of nickel matte, which eliminates high-temperature oxidation and reduction operations.

J & L: Multi-Process Steelmaker

Jones & Laughlin Steel Corp. reports it is making ingots by more processes than any steel company in the U. S. Processes involve the bessemer, duplex, open hearth, electric, and basic oxygen furnaces. This summer the company will start to build the two largest basic oxygen furnaces in the world and one of this country's biggest blast furnaces.

Liberia Iron Ore Project

The Mount Nimba iron orebody will be developed by joint effort of Liberian American-Swedish Minerals Co. (Lamco) and Bethlehem Steel Corp. The area in Liberia is believed to contain one of the biggest high grade iron ore deposits. The major mine will be located about 170 miles from the coast.

Lavender Pit to be Expanded

Phelps Dodge's Lavender Pit copper mine at Bisbee, Ariz., will be expanded to the southeast, extending the mine's life by about seven years. Newly proven ore should assure remaining total life of about 15 years. The enlargement, costing about $5 million, will not step up the production rate. The pit accounted for about 16 pct of the company's output in 1958.

Freshman Engineering Enrollment Drops Sharply

For the first time in eight years, enrollment of freshmen in engineering curriculums has declined steeply. In 1958, 70,029 engineering freshmen enrolled compared with 78,757 in 1957, a drop of 11.1 pct. Total enrollment in all colleges, however, continued to climb and was more than 7 pct higher than in 1957. Engineers Joint Council reported the decline was laid to: inaccurate appraisal of engineering career opportunities, concern about the rigors of an engineering curriculum, and increased student interest in other scientific fields.

UN Study Group on Lead and Zinc

World cutbacks in lead and zinc supplies were recommended by a United Nations-sponsored study committee composed of representatives of 21 nations. The group announced that producer nations came to an agreement on cutting production or exports in the second half of 1959. Some 45,000 tons of lead and 52,000 tons of zinc, including cutbacks recently announced by individual firms, will be taken off the market.

Monticello Mill to Close Down

The only AEC-owned uranium mill, the Monticello, Utah, plant will be shut down and maintained in a stand-by condition, on or about January 1, 1960. The mill, now operated by National Lead Co., is treating some 300 tpd of ore—about the minimum economic operating rate. Ore deliveries have recently average only 100 tpd and a substantial part of mill feed has been drawn from accumulated stockpiles.

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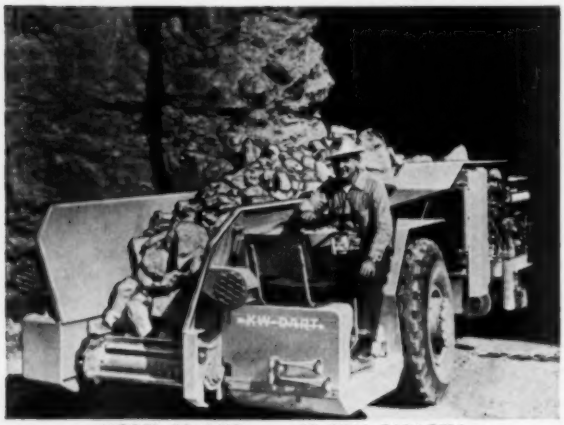

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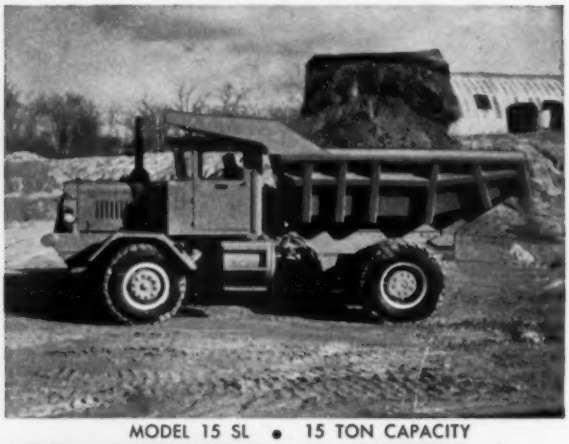

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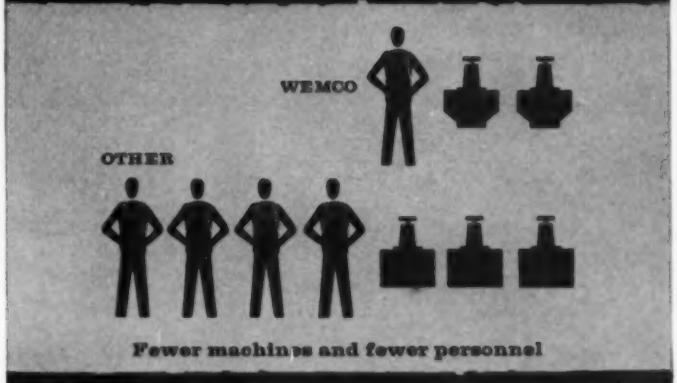
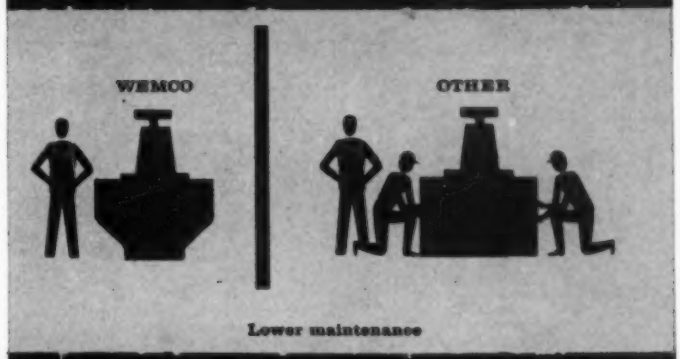


Fewer machines and fewer personnel



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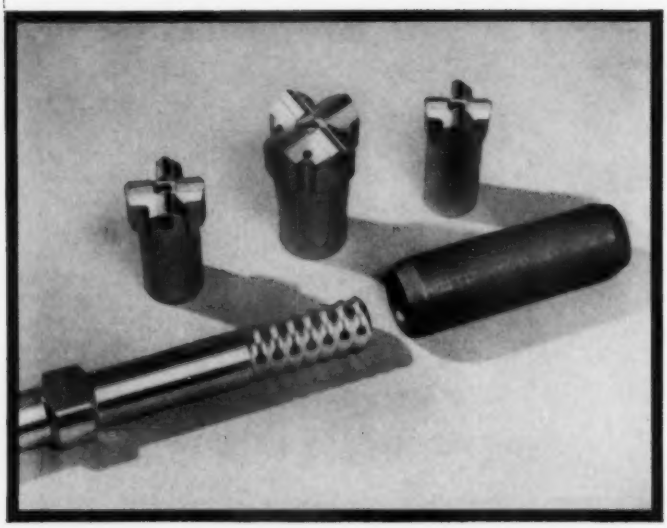

Here's proof Coromant rope-thread bits and steels SAVE TIME AND MONEY

"Up to double the footage between sharpenings!"
"Premature rod breakage is almost non-existent!"
"40% more usable life—more resharpenings!"
"Bit and rod life are well above average!"
"Uncouple by hand all the time!"
*"More rigid—drills straighter holes!"**

**Names of men quoted available on request*

The comments above are actual quotes from project managers, job superintendents, and drill superintendents who have tested new Coromant rope-thread bits and steels. They've learned, on-the-job, the benefits they—and you—can expect!

For example: The new rope-thread (only two turns per inch) holds tight in use, yet permits hand uncoupling. Reports show that the time saved results in more footage drilled per shift. Bit footage is well above average too, with less loss of carbide inserts. Prime quality ore plus nickel-chrome alloy permits cold-rolling from billets for greater strength, life and rigidity. And only with Coromant rope-thread steels can you re-thread without heat treating, too. Do it yourself, or at any nearby machine shop.

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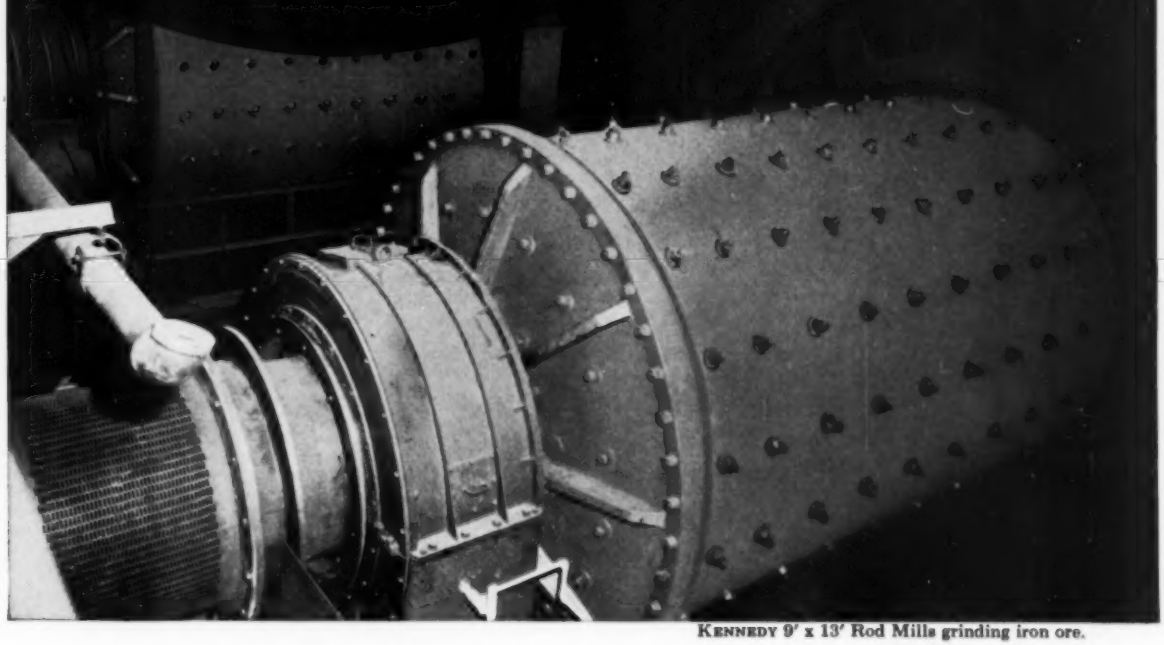

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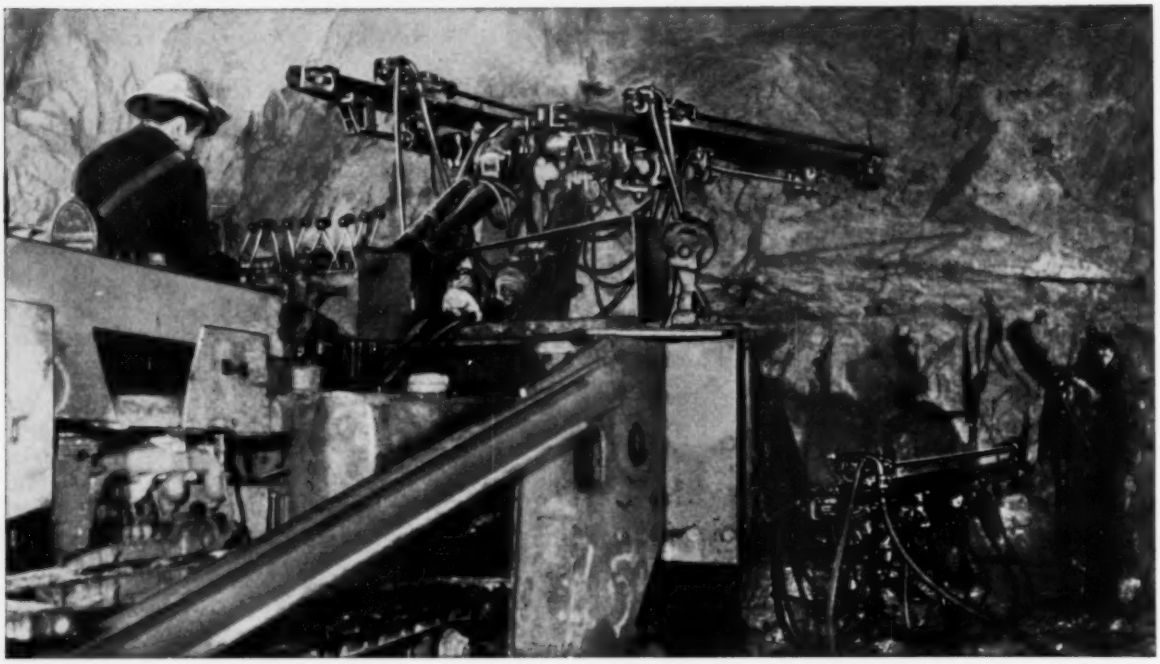
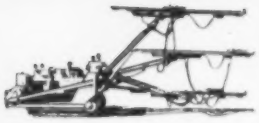
HYDRA-BOOMS

speed underground drilling in Canada's URANIUM MINING BOOM





Unlike the gold rush of Klondike days, the uranium boom in Canada's Algoma Elliott Lake area is spearheaded by the most efficient *mechanized* equipment. To speed up drilling with minimum effort, the Panel Mine of Northspan Uranium Mines Ltd. is using four Ingersoll-Rand Hydra-Boom drilling rigs, one of which is shown above, operating 1700 feet below the surface.

Each tractor-mounted rig carries three heavy-duty I-R drifter drills mounted on Ingersoll-Rand Hydra-Booms, providing smooth effortless hydraulic control of all drill motions. Booms are raised or lowered and swung from side to side and drill guides are extended, retracted, dumped and swung at the touch of a throttle—all drills easily controlled by one rig operator. Using 1⅛" round steel and 1¾" tungsten carbide insert bits, these rigs are used in a room and pillar trackless mining operation, teamed with 48" ramps mounting 30-hp I-R slusher hoists.

I-R Hydra-Booms represent the last word in *mechanized* rock drilling—convert setup time into drilling time and increase production by as much as two-to-one. Rugged, versatile and easy to operate, Hydra-Booms are designed and built to withstand the punishment and abuse inherent in underground mining operations. Swing and lift cylinders are double acting, fast moving, and locked to prevent dropping the boom if hydraulic lines are broken.

Ask your Ingersoll-Rand drilling engineer for complete, cost-saving facts 'about I-R Hydra-Booms. Or send for a copy of new bulletin 4196.

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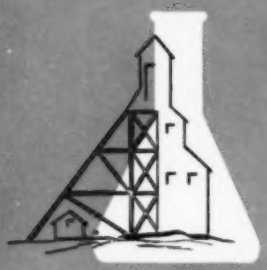

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improves filtration, cuts concentrate drying and shipping costs

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Use of 4¢ per ton of AEROSOL OT has cut concentrate freight costs 10¢ per ton!

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Thus, a penny per ton for AEROSOL OT with a resulting drop of 2 percentage points in filtrate moisture produced a net saving of 10¢ per ton on preparation costs.

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Traylor TF Fine Reduction Crusher produces 5/16" to 1¼" material in large capacities. Over a half century of engineering experience is built into all Traylor crushing machinery. Write for Bulletin No. 127.

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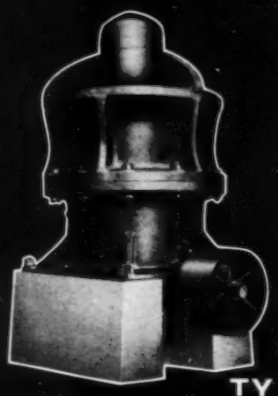
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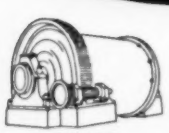
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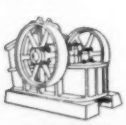
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MINING engineering **DRIFT**

LOOK-AHEAD TOOLS FOR MINING

Mining engineers, and the industry, have done much in past years to develop new tools, new processes, new techniques which have benefited engineering and industry as a whole. Beneficiation has a particularly bright record . . . things like filters, thickeners, and so on, have gone on to become the foundations of other industrial processes than mining.

But, right now mining and the earth sciences seem to be getting little of the research and development limelight and dollars. Much of the work, and most of the dollars are Government-controlled at the moment. As pointed out in *Drift* last month, Mohole is one of the few IGY-type projects of even indirect benefit to the mineral industries. What else can be done, other than push for more attention to the mineral industries?

Tremendous sums are being spent to find new ways to do old things, and in some cases, as in the satellite program, to do completely new things. In business practice, too, there is a surging application of engineering and research. With all the new ideas being developed elsewhere it would seem that this is a period for the look-ahead mining engineer and his company to look at what other fields are doing, to find tools which can find, move, or treat ore—better, or cheaper.

In MINING ENGINEERING for May there were three articles that fit this definition: new tools adapted from other industries. (*Photogrammetric Methods*, p. 497; *Gyro-Compass Surveys*, p. 521; *Electron Diffraction*, p. 535). Fresh ideas, dozens of them, and workable ones at that, will contribute to what Professor Gene Pfleider calls the "forward look in mining."

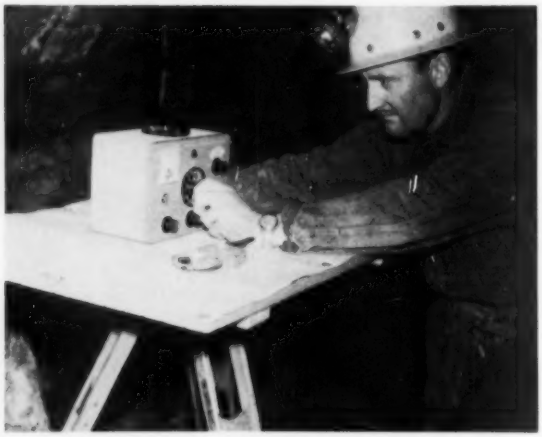
Interestingly, all of the three items mentioned above from the May issue make some use of photography. We recently saw samples of the results of another photographic tool and mention it merely to make the point that looking afield can be profitable.

If you can call a 4-in. wide negative, microfilm, there is a new microfilm technique on the market that *might* have application to mining. Recently demonstrated by Kueffel-Esser (non-advertiser), the technique is tailormade for handling large drawings. How many mining geology departments and drafting rooms have any protection for large working maps and geologic plans in case of fire or loss? How many home offices have reference sets of all field drawings? Perhaps this technique can save you money or provide greater information safety. K & E would surely be delighted to tell you more about it.—*Rixford A. Beals.*

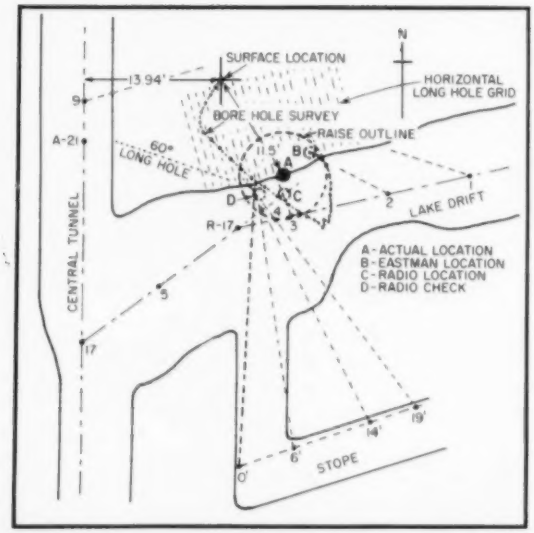
NEW TECHNIQUES FOR OLD MINES

New approaches, new techniques, new equipment hold hope for new life in old mining districts. Large diameter drillholes for ventilation, underground radio triangulation, hoist ropes with conductors for communications, suspended work cage raising, and circular steel ore passes are now being used to revive a promising area in the Front Range mineral belt of Colorado.

by ALFRED G. HOYL, PAUL L. GODDARD, and WILLIAM R. SIROLA



Triangulating underground with Heath DF-2 portable radio direction finder. Power supply was 12-v storage battery.



Vent hole bottom was located by radio, bore hole survey.

A good place to look for elephants is in elephant country, and old mining districts are certainly elephant country as far as minerals are concerned. In many areas probably more ore is still in the ground than has been taken out. The old timers were good miners and hard workers and when they left ore behind, it was usually for good reason; but many an old mining district has been revived by new approaches to old problems, taking advantage of new techniques and new equipment.

One of these is the Front Range mineral belt of Colorado, which has produced minerals for the past 100 years through the ups and downs of mineral prices and the general economy. Gold, silver, copper, lead, and zinc have been found in abundance in the complex sulfide veins of the area. Between Idaho Springs and Central City lie several strong veins which have been mined successfully in the past. The two strongest of these veins, striking northeast-southwest, (Lake-Bald Eagle), and northwest-southeast, (Crown Point-Belman), and dipping northeast and northwest, respectively, intersect in a flat *X* near the head of Virginia Canyon. From the lowest drainage of the area, Clear Creek Canyon, the old timers drove the Central, or Big Five, haulage-drainage tunnel due north. It intersects the two veins 8460 ft from the portal and 1670 ft below the surface. The two veins were mined successfully at the surface and at the tunnel level. Without an opening to the surface at the inside end of the tunnel, ventilating became very difficult as the stopes were opened up, and mining ceased in 1929. Vertically, 1200 to 1600 ft of virgin ground remains in the veins.

MINE REHABILITATION

Clear Creek Mining Co., a joint venture of Contract Engineering Co. of Denver, and Beaver Lodge Mines Ltd. of Vancouver, B. C., set up the Lake Central project in 1957 to rehabilitate the Central tunnel, ventilate the intersection area of the two veins, and explore and develop the untouched portion of the veins.

A. G. HOYL and P. L. GODDARD are, respectively, President and Secretary-Treasurer of Contract Engineering Co., Denver. W. R. SIROLA is a Geologist with Beaver Lodge Mines Ltd., Vancouver, B. C.

Several new techniques were used, which are developing into useful mining aids. Outstanding features of the project are described herein.

Geology and Ore Deposits: The untouched veins extend through rock known as the Idaho Springs formation and are typical mesothermal fissure fillings. The fissures are fairly regular in strike and dip, and irregularities, where present, commonly provide favorable structures for deposition of ore minerals.

The principal types of ore are pyrite-gold, galena-sphalerite, chalcopyrite, and tetrahedrite. There are many pegmatites, granite porphyries, quartz monzonites, and bostonites forming dikes and lens-shaped masses which have been intruded into the pre-Cambrian gneisses and schists of the country rock. Vein intersection and deflections in dip and strike, and portions where veins cut or follow dikes, are favorable areas for deposition of ore.

Ventilation Drillhole: It was decided to ventilate the tunnel by drilling a large diameter hole from the surface to the area where the tunnel intersected with the veins. The vent hole would provide an opening to the surface, ventilation, a duct for power lines, and a means of bypassing the old workings using the suspended work cage system of raising. Also, the vent hole could be drilled as the tunnel was being rehabilitated.

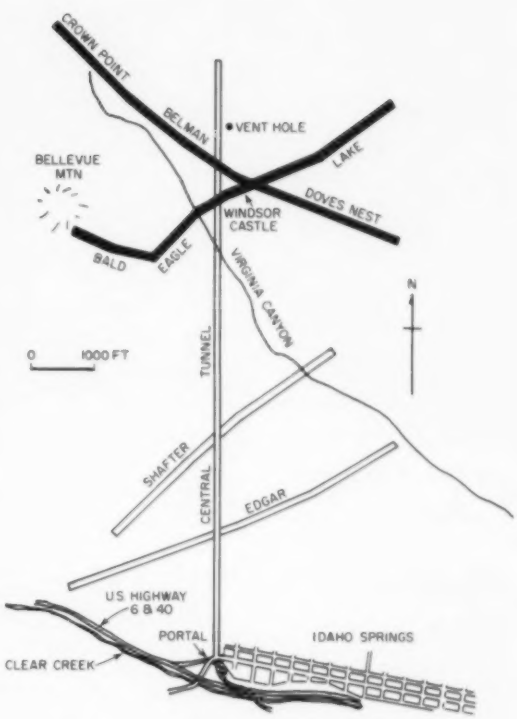
A large churn drill, or cable tool rig, was used. A 16-in. diam hole was desired, and it had to be as close to vertical as possible. Sections of very hard rock were expected and it was felt that the cable tool rig could do the most economical job. The vein intersection at the tunnel level was picked as a target as it underlay a good surface site, and the tunnel, intersecting the drifts on the vein, would be easier to hit than a single opening.

The vent hole was drilled to 500 ft, but at 360 ft it passed through a vein which began to cave slightly. The hole was then reamed to 22-in. diam to a depth of 420 ft, and 16-in. casing was set to this depth. Below 360 ft the rock was extremely hard, essentially a fine-grained granite gneiss changing to granite pegmatite at intervals.

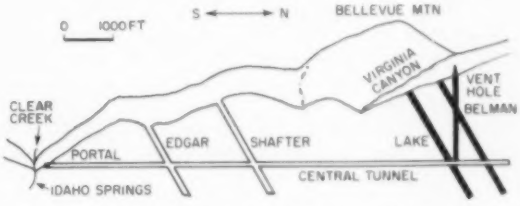
At 500 ft the hole size was reduced to 11 in. for faster progress, and to obtain a straighter hole. It was planned to ream the hole to 16 in. after connecting with the underground workings. Below 500 ft the rock continued to be extremely hard, except for a few bands of schist and coarse-grained pegmatite. Progress was very slow. Footage per 24-hr period varied from 24 ft to 6 in. and averaged 6½ ft. It took eight and one half months to complete the hole.

After holing through, the hole was reamed to 16-in. diam from 500 ft to 700 ft. From 700 ft to the tunnel level, the hole was left 11-in. diam. Eventually it is planned to raise up the hole 900 ft, to 700 ft from the surface, and ream the balance of the hole to 30-in. diam. The hole was exceptionally straight and smooth and has made an excellent vent.

Radio Location of Vent Hole: As the vent hole approached bottom, it was important to locate it exactly. The tunnel had been cleaned up, caves removed, retimbering done where necessary, drainage established, and the intersection target of the vent hole separated by bulkheads from the old workings. Ventilation for this work, done on a one shift basis five days a week, was provided by a 500-cfm stationary Le Roi-Westinghouse compressor through a 4-in. compressed air line. This was not sufficient for any extensive drifting to connect with the vent hole. The vent hole was filled with 1500 ft of water.



Vein system of Clear Creek's Central tunnel.



Profile of Central tunnel. Note veins and vent hole.

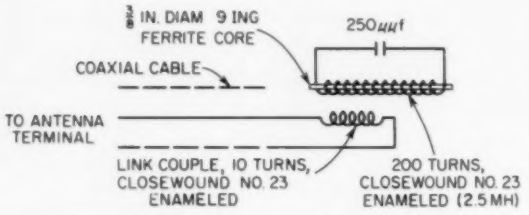
It was planned to long-hole a closely spaced grid of horizontal holes at the tunnel level so that the location of the hole could be determined as it approached bottom. This would increase the target area and drain the vent hole. If the grid could be drilled accurately and quickly enough, it would eliminate the danger of drilling into the high-pressure column of water.

Borrowing a technique used successfully by Anaconda Co. at Butte, Mont., and with the assistance of the Bureau of Mines and USGS, a radio transmitter and receiver were assembled and the bottom of the hole located by radio triangulation. In addition, a borehole survey was conducted by Eastman Oil Well Survey Co.

The transmitter was powered by a 12-v automobile storage battery. Plate voltage of 315 v was supplied by a vibrator power supply built into the transmitter case. Output of the vibrator power supply was unfiltered, to provide a tone modulation of the radio signal. The transmitter consisted of a

single 6L6 electron-coupled oscillator, amplifier. The transmitter had a tuneable oscillator covering the frequencies of 200 to 240 kc, and a tuned plate circuit.

A tuned antenna was made to be lowered into the hole to concentrate on the signal. It consisted of a coil wound on a ferrite rod with a series condenser; the circuit was tuned to 215 kc. This tuned antenna was link-coupled to a 72-ohm coaxial cable 1800 ft long, and the assembly potted into a weighted probe.


3/8 IN. DIAM 9 ING FERRITE CORE
250 μμf
COAXIAL CABLE
TO ANTENNA TERMINAL
LINK COUPLE, 10 TURNS, CLOSEWOUND NO. 23 ENAMELED
200 TURNS, CLOSEWOUND NO. 23 ENAMELED (2.5 MH)

ANTENNA COIL MOUNTED IN POTTED, WEIGHTED PROBE

A Heath DF-2 direction-finding receiver was used. This receiver tunes from 200 to 400 kc, plus the standard broadcast band of 550 to 1700 kc. The receiver is equipped with a rotating ferrite loopstick antenna, and a signal strength-null meter. It was found that the null was much more pronounced than the maximum and also much sharper.

To locate the bottom of the vent hole, an automobile was driven close to the collar of the hole and the transmitter was connected to the car's battery. The potted, tuned antenna, mounted in the probe, was then lowered to the bottom of the hole, using the coaxial cable to support the antenna probe and deliver power to the antenna. The cable was connected to the transmitter and the transmitter tuned to 215 kc, the resonant frequency of the tuned antenna. The drill hole was 1625 ft deep at the time the location was made.

The transmitter was placed on a plane table under pre-surveyed stations in the tunnel and intersecting drift. Readings were taken of both the null and maximum at each station.

The signal picked up by the receiver through 60 ft of rock was very strong. It was found that reradiation from the track and air line was tending to alter the direction fixes perpendicular to the track and air line. A section of track and air line was removed and the survey re-made. A check was also made from a small stope 40 ft long, 20 ft above the track, and 20 ft to the south of the drift up the dip of the Lake vein. The survey showed the hole to be almost directly above the drift and 12 ft east of the tunnel. Allowing for drift as the hole continued down, the radio survey was accurate to 1 ft.

The horizontal, parallel, long-hole grid was drilled on 11-in. centers, giving about a 30-ft square target north of the Lake drift and just east of the tunnel.

The hole came down in the north rib of the drift just 12 ft east of the tunnel, intersecting the collar of one of the long holes. The 1670-ft hole was only 12 ft from true vertical when completed. The drill holed through early one morning while the mine crew was off shift. The escaping 1500 ft of water stripped the back and rib of the drift of 6 to 18-in. of rock.

The intersection locale had been declared off limits for two days prior to holing through, but it was expected the holing through could be seen from a safe distance. Unfortunately, no one witnessed the operation from underground.

The exceptional straightness of the drillhole was maintained by constantly checking drift of the vent hole with an Eastman single-shot drift indicator, which was lowered in the hole for every 5 to 10 ft of progress in a tube welded to the side of the 20-ft bailer. The hole was straightened if the drift exceeded 1°.

As it reached the depth of 1500 ft, the hole was surveyed by Eastman on 20-ft intervals using an Eastman DX multiple-shot directional survey instrument, and again after the hole intersected the Lake drift. The survey was accurate to 6 ft and was essential in interpreting the pinpoint location made by radio triangulation.

Raising With Suspended Work Cage: When the vent was completed, natural circulation of air down the hole and out the tunnel was sufficient to permit opening the bulkheads and allowing a reconnaissance of the old workings at the tunnel level. As expected, they were badly caved, and it was decided to raise above the old workings and cut into the veins at 276 ft and 576 ft above. This would bypass the old workings and open a potential 90,000 tons of gold, silver, copper, lead, and zinc ore, and put the project into pilot production.

The vent hole had been located and planned for a suspended work cage raise. It was decided to immediately go ahead with the raise, bypass the old workings, and establish the 276-ft level. This has been named the Sayre level after the pioneer mining family who originally started the Lake Mine and were responsible for much mining development in Colorado and the West.

A hoist, hoist house, headframe, and positive reversible blower were installed on the surface at the collar of the vent hole, and a work cage was fabricated.

A three-conductor electric hoist rope, an Eimco M-21 rocker mucker, an 8-ton battery locomotive, and eight 91-cu ft Granby dump cars were obtained.

Suspended work cage system of raising at other operations was studied before decision to employ the cage in project.

The tunnel was retracked with 30-lb rail and a dump block installed at the waste rock dump.

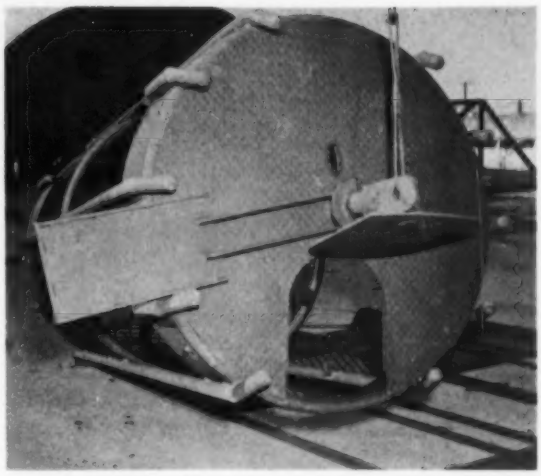
In planning the vent hole and raise, much thought was given to the suspended work cage system of raising and a study was made of the raise made with this method at the Irene shaft in Leadville, Colo., by Resurrection Mining Co. [An excellent article, (Bureau of Mines Information Circular 7868), by R. L. Bolmer and B. B. Greenlee, is available on the Irene raise.] H. Chapman, shift boss on the Irene raise, was retained for the raise work at Clear Creek.

A number of recommendations and changes in the suspended work cage system of raisings were made by B. B. Greenlee, and these were followed in setting up the raising operation. Reports on other suspended work cage raise projects in Ducktown, Tenn., and Ironwood, Mich., were also studied.

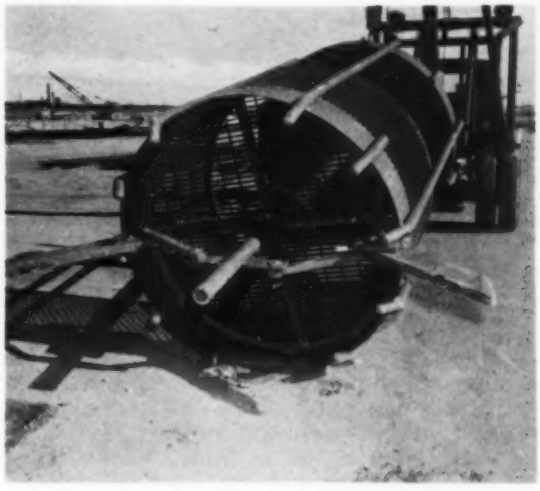
Since communications is a problem in work cage raising, a phone line was installed from the hoist house at the collar, overland to the tunnel portal and through the tunnel to the foot of the raise, with phones at the hoist, portal, and tunnel raise station. A second independent phone at the hoist connected to a phone in the work cage, through the conductors in the hoist cable. The hoist cable carried three conductors. The first conductor and ground was used for the phone, the second and ground for the hoist bell signals, the third and ground for an emergency hoist-stop button. Twenty-four volts were used for the bell and stop button circuit, and two standard No. 6, 1½-v dry cells for the phone circuit. Phones were surplus military EE-91 units. No trailing electric cables were necessary.

Raise Design: The raise was to be circular in section, 9-ft diam, and 600 ft high. Provision was made for steel sets, two 24-in. steel pipe ore passes, man and material cage, ladder way, air and power lines, and ventilation equipment. A large station cut at the foot of the raise was adequate for two rounds of raise muck and allowed the work cage to pass.

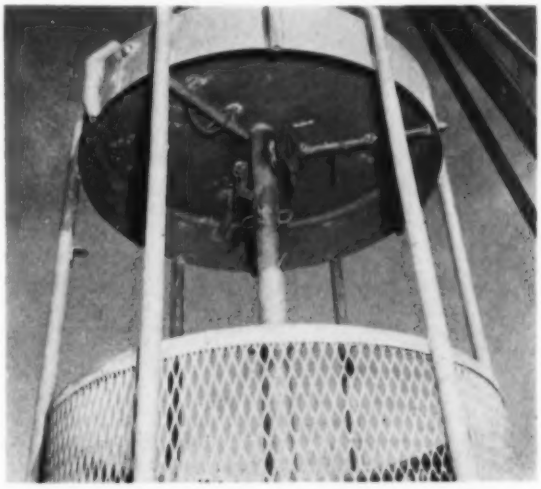
Raising Procedure: After the work cage was connected to the hoist cable, communication lines plugged into the cable fittings, and signals and phone checked, the raising crew and equipment were loaded into the cage. The cage was raised to working distance from the back, and three spuds set to hold the cage firmly in position. The crew then mounted to the top of the cage, barred down, set up their drills, and drilled out. The round was loaded, using delay electric caps, the spuds withdrawn, and the cage lowered. The cage was pulled away from the base of the raise by the mucking machine and the top tilted over, leaving the cage in an upright position, but out of line of falling rock. The hoist cable and communications were disconnected, and the hoistman advised over the phone to raise the cable. As soon as the hoist cable was clear of the top of the raise, about 200 ft above the round, the hoistman gave the all-clear signal and the round was detonated with a Dupont 240-v condenser-discharge blasting machine. The muck fell directly to the foot of the raise. As soon as the hoistman heard the shots fire, he turned on the positive blower, exhausting the powder smoke out of the top of the vent hole, and lowered the hoist cable back to the foot of the raise. The cage was then reconnected to the hoist cable, communication lines replugged, and a cycle repeated. The crew could return to the working face within 10 min.



Top deck and drilling surface of work cage shows trap door and extendable drilling platform for outside drill holes.

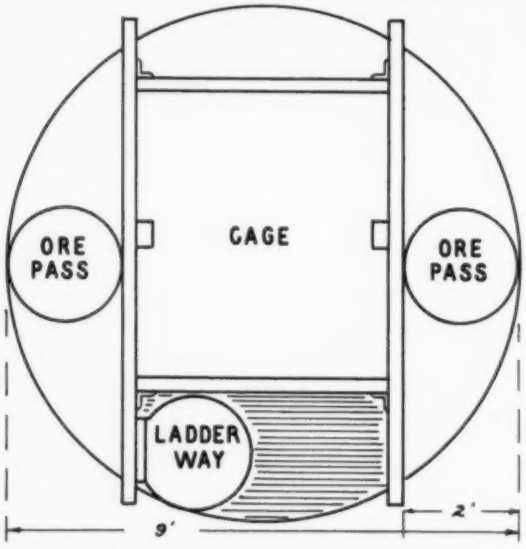


Note safety dogs beneath bottom deck of cage.



Spuds and setting jack located inside top deck.

Cage in raise at the Sayre level. Hoist cable was also used for communications. Clevis attached it to work cage.



Dimensions and design of the 600-ft high raise.

During loading, muck at the foot of the raise was removed.

A 2-in. heavy duty air line was carried up the side of the raise to within 50 ft of the back. A 100-ft bull hose, suspended beneath the cage and attached to a manifold in the cage, was connected to the air line as the cage was raised to the back.

Considerable water was flowing down the vent hole. Before drilling started, this water was picked up in a funnel device which was clamped to the cable. The water was conducted through a rubber hose to the upper section of a two-compartment water tank in the cage. The lower portion of the tank was arranged so that it could be pressurized by air and force water to the drills. The pressurized section was filled two to three times per round from the upper water reservoir.

The rock was extremely hard, and drilling was done with two Atlas Copco stopers using ⅞-in. hexagonal steel, and 1⅝-in. tungsten carbide bits. The fast, light blow of the Atlas stopers seemed to give good drilling speed with minimum damage to bits and steel. A 24-hole, 7-ft round was drilled; holes were loaded with 45-pct, 1¼ x 16-in. Gelex dynamite.

Hoist Cable and Electrical Connections: Water flowing down the vent hole supplied handy drilling water and was very helpful in minimizing dust and powder fumes. But it did make necessary very thorough protection of all electrical connections and phones. Since communication lines through the cable had to be disconnected for each round fired, it was essential to have effective and well-protected connections. The work cage phone was kept in a metal box bolted to the steel roof of the cage. A four-conductor rubber electrical cable led from the phone box through the top deck of the cage to the hoist cable connection. A three-conductor cable led from the phone box to a push button box which operated the bell and emergency hoist stop. It was necessary to encase the push button box in a heavy vinyl plastic bag which was taped tight to the rubber cable and thoroughly waterproofed with Scotchkote electrical coating. The buttons were operated through the plastic bag.

The phone set including the batteries was also encased in a heavy vinyl plastic bag which was taped tightly to the two phone circuit wires and the receiver wire, which were also waterproofed. The phone receiver was encased in an individual plastic bag. It was necessary to open the phone circuit and crank the phone through the plastic bag. This system prevented any water or drill cuttings from entering any of the electrical connections and there was no trouble with the communication system.

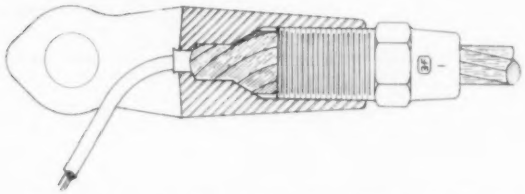
The detachable connection from the work cage to the end of the hoist cable was a four-way, cannon, aircraft type plug-in connection. Whenever separated, male and female ends of this connection were protected by screw caps.

Hoist Cable: The hoist cable was a 1-in., 6 x 21 FW Wisscolay gray strand, right lay, plastic impregnated, conductor core rope furnished by Wickwire Spencer Div. of Colorado Fuel & Iron Corp. The conductors in the hemp core of the rope precluded use of a zinc socket or standard cable clamp. Instead, fittings manufactured by Electroline Co. of Chicago, were modified and attached. The electroline fittings are three unit assemblies consisting of a sleeve which slips over the end of the wire rope, a plug which is inserted to separate and hold the strands of wire in the sleeve, and a covering socket. This combination locks the cable to make a strong, flexible, durable connection. The fittings were modified by drilling a hole through the plug and the free end of the fitting through which the hemp core was passed. Transition from plug to sleeve was made through a short piece of copper tubing. A drum socket was used on the hoist end, and a clevis on the cage end of the rope. The entire unit, including the

female cannon plug on the hoist end, was encased in a section of 5-in. pipe into which a second clevis had been welded. This, in turn, connected to the cage with a 1½-in. steel pin.

The female cannon fitting was led through the wall of the 5-in. pipe and protected by a projection of 2-in. pipe which was covered with a pipe cap when the cable, free of the cage, was being drawn up the raise and vent hole.

The conductors at the hoist end of the rope were passed out of the drum socket in the hemp core and connected to a very simple collector ring attached to the hoist drum.



Before installation, the modified Electroline fittings were tested with a pull of 46,800 lb, or about half the rated strength of the hoist rope. Since the work load was approximately 5000 lb the test loading was nine times the work loading.

Subsequently, the same rope and fittings were tested to destruction, and failure occurred at a loading of 79,785 lb. Catalog-rated breaking strength for the hoist rope is 83,600 lb. The Electroline fittings were more than adequate in strength and gave enough freedom to the hemp core to fully protect the conductor wires to almost breaking strength of the hoist rope.

Hoist Installation: The hoist was rebuilt from a Denver Engineering Works machine with a 4-ft diam drum 20 in. wide. It was powered by an electric 15-hp, 1200-rpm wound rotor motor, operating through a 10:1 ratio speed reducer. The combination provided a speed of about 6 rpm on the hoist drum and rope speed of about 75 fpm.

An electrical brake was installed on the coupling between the motor and speed reducer. Power failure, or use of the emergency stop button, would set the brake and stop the hoist.

A large ammeter was provided for the hoistman to help warn if the work cage had hung up. The working load was 5000 to 6000 lb, and the hoist was powered so that in the event of a hang-up, the motor would kick out before any damage could occur.

Work Cage: The work cage design was very similar to the one used at the Irene shaft in Leadville, Colo., and used the same type safety dogs. It is circular in shape with a maximum diameter of 68 in. Overall height is about 10 ft. The unit weighs some 2000 lb.

Performance: About 100 ft of raise was driven experimentally to work out the round and train two raise crews, while surface facilities, heavier track, and additional haulage equipment were installed. No particular effort was made to make progress during this period as the small haulage equipment used in rehabilitating the tunnel was entirely inadequate and the raise consequently was muck bound.

When raising began in earnest, the average advance per shift was 6 ft, or one round per shift. The raise was worked in two 8-hr shifts, six days per week, or 12 shifts per week. It was relatively easy to average 70 to 80 ft per week.

The bottleneck in the operation was drilling. Two stopers were operated from the cage, but, because the rock was so hard, most of the shift was spent drilling out the round. Loading, blasting, mucking up, and getting to and from the work surface was fairly easy. The rock broke nicely to the large vent hole.

The raise crew consisted of shift boss, two miners in the cage, mucking machine operator, trammer, and hoistman.

The Sayre level station, 276 feet above the tunnel level, is being cut and drifts have been started to intersect the Lake and Belman veins. It is planned to continue raising to the 600-ft point as soon as the station is completed. Complete data on the raise as to footage and costs will not be compiled until the second stage of the raise is completed.

The hard rock stands excellently and the raise so far requires no timbering and only steel support sets for shaft guides, ore passes, and ladder ways.

The new techniques described herein have been used in several instances with very good results. It is quite possible that, with the application of the newest, most efficient mining techniques, many orebodies previously out of reach can be developed and placed in production profitably.

SAFETY PROVISIONS

Safety was provided through:

- Double communication system
- Heavy construction of work cage
- Extra large hoist rope
- Low speed of the hoist
- Electric brake on the hoist
- Constant scaling and barring down
- A 600-ft, 5000-lb test nylon escape rope carried in the work cage at all times. Special nylon bosun chairs and Rose Mfg. Co. slip fittings for the nylon rope were provided, which allow a man to ride down the escape rope in bosun's chair which is completely controlled at all times.
- Waterproofing of all electrical and phone equipment
- Safety belts for men working on top of the work cage

The cooperation and assistance are gratefully acknowledged of D. F. Farris, President, Beaver Lodge Uranium Mines Ltd., Vancouver, B. C., and President of Clear Creek Mining Co., Denver, Colo.; E. H. Ellis, Grant, Shafroth & Toll, Denver; B. B. Greenlee, former general manager, Resurrection Mining Co., Leadville, Colo.; W. Tesch and R. L. Bolmer, mining engineers with USBM; R. Barnett, Radiation Laboratory, USGS; W. L. Scott, G. A. Franz, and Norman Blake of the Colorado Bureau of Mines; R. P. Corbett, planning and research engineer, Anaconda Co., Kelley mine, Butte, Mont.; Franklin & Perry Drilling Co., Ozona, Tex.; Eastman Oil Well Survey Co., Denver; Heath Co., Benton Harbor, Mich.; Electroline Co., Chicago; R. H. Sayre, Mining Engineer, Denver; J. C. Farmin, underground engineer, Anaconda Co., Butte, Mont.; R. Farmin, assistant manager, Day Mines, Inc., Wallace, Idaho; Colorado State Highway Department; the crew and miners of Clear Creek Mining Co.; and the old timers who have never lost faith in the Front Range mineral belt of Colorado.

SHAFT SINKING AND DEVELOPMENT UNDER HOT WATER CONDITIONS

Mining near a Nicaraguan mountain chain that includes sometimes-active volcanoes has brought some unusual difficulties to the Limon gold mine.

by DONALD L. ANDERSON

Presence of hot water brought on by volcanic action nearby has severely complicated mining in the Limon gold mine in Nicaragua. Routine pumping problems have been multiplied and ventilation is a major problem. Enclosing rock is so hot that 20 pct of all power generated at the mine is consumed by forced ventilation. But hot water underground, however disagreeable and troublesome, may be handled and surmounted like any other difficulty if the estimated profit margin permits.

Empresa Minera de Nicaragua's Limon mine is a 400-ton gold-silver producer located in western Nicaragua about 60 miles northwest of the capital city, Managua, and some 45 miles from the Nicaragua-Honduras border. Limon is situated in a low-lying district with a nearby chain of active and semi-active Tertiary volcanoes.

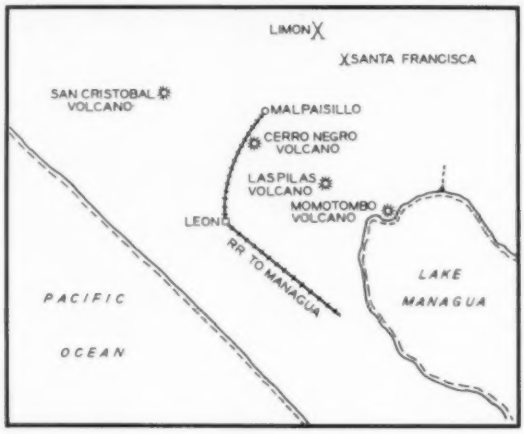
From an average elevation of about 3000 ft, the mountains slope northeasterly, and at the mine the elevation is only about 200 ft. Andesite is the prominent rock of the district. Rhyolite is common and some strong basic flows and intrusives are encountered.

The most prominent, though not the highest, peak of the mountain chain is Momotombo, which has not erupted for many years, but has a slight wisp of vapor continually rising from its crater. The most active volcano is the Cerro Negro, which erupted in 1947 and again in 1950. The volcano Las Pilas recently evidenced a new fissure, which is erupting steam and occasional black smoke.

Ore Zone: The main vein and auxiliary veins are oxidized epithermal type gold-silver veins located along prominent fault areas. Ore width varies from a few feet to about 40 ft, and in most locations a heavy, soft, brown gouge is found in the hanging wall. Mining generally is done by cut and fill and square set methods although shrinkage stoping has recently been used at the Santa Francisca section.

HOT WATER ENCOUNTERED

Apart from isolated reservoirs, hot water was first encountered on the 634 level, 67 feet below sea level, when the main vein was intersected by crosscutting from the main shaft. The water had a temperature of 118°F and, when the vein was diamond drilled, an installed pressure gage showed a head of approximately 30 ft of water. Since this was to be the main haulage level, it was decided to sink a shaft in the impervious footwall of the vein and crosscut the vein 100 ft below the main level, in an effort to lower the water level and permit drifting under more favorable conditions. The shaft



was sunk as planned, and the crosscut to the vein at this lower level produced water at a maximum of 122°F. Ventilation was maintained by a 15-hp propeller fan that forced air, through 18-in. collapsible vent tubing, down the shaft and up to the face. Water at 120°F can be endured on the hands without too much discomfort, but care had to be exercised to maintain an adequate ditch to keep water from the men's feet.

The vein was crosscut with difficulty but, fortunately, the inflow of hot water was small; with controlled drilling it never exceeded 80 gpm. The water occurred mostly in fractured areas which paralleled the dip of the vein and after one or two days of draining it diminished enough to permit a further advance. When the crosscut was completed, a deep well pump was installed. The hot water so far encountered was very clear, averaged 120°F, and had a slight odor of hydrogen sulfide.

Work was meanwhile in progress on a new shaft about three miles to the southeast and slightly closer to the active volcanic region. Here a vertical shaft was being sunk to explore the old Santa Francisca and San Luis veins which had been worked extensively 30 to 40 years ago when, reportedly, operations ceased because of excessive hot water on the lower levels. Diamond drilling now indicated values but very little was known about these old workings. Hence, a decision was made to sink the shaft to the 700-ft level (455 ft below sea level) and crosscut the vein at this elevation. The idea was to drain all upper zones, as had been done to a limited extent in the main orebody.

The shaft was two-compartment with standard timber sets; the timber used was nispero (or mora),

D. L. ANDERSON is Associate Professor, Mining Engineering, School of Mineral Engineering, University of Washington, Seattle.

a type of local iron wood, which is very heavy and difficult to frame, but extremely rot resistant and very strong. Bearer sets were placed at intervals not greater than 80 ft and at all shaft stations. Since the rock was firm, shaft lining was used only in certain sections. Drilling was carried out with light weight sinkers and all mucking was done by hand.

The Santa Francisca shaft was sunk as a routine operation in firm andesite, with the final station cut at the 700-ft level. After establishing a loading pocket, the crosscut to the vein was pushed. The footwall of a hard quartz vein was found at 300 ft and corresponded to the projection of the surface outcrop dip and strike. Up until vein exposure, a few quartz stringers had yielded a small quantity of hot water at 120°F. These stringers were similar in dip and strike to the main structure. When entered, the vein likewise produced water at 120°F, though not in big enough volume to stop the advance. Despite forced ventilation, working conditions were extremely disagreeable.

During shaft sinking in the cool footwall, no ventilation problem existed, but after the station and loading pocket were completed, provision was made for ventilation, in anticipation of conditions to be encountered. One 15-hp propeller fan was installed on surface and delivered 8000 cfm through an 18-in. metal vent tube to the crosscut below. When the first flow of hot water entered the crosscut, a second fan was placed on the level and operated in series with the first. As in the main shaft, drainage to the sump had to be maintained with an adequate ditch, and flexible vent tubing had to be kept within 15 ft of the working face. In addition, cool air had to be directed on the pump motors to prevent overheating and failures. When power failed on this level, it was impossible to remain at the face for more than 5 to 10 min.

From experience gained so far, it was decided that if values were not encountered on this level, no attempt would be made to pump out any excess hot water that might develop.

In the main shaft operation it had been found that a deep well pump would handle the clean water and a bulkhead would isolate this hot water from the rest of the mine. A diamond drillhole was not carried in advance of the face because it was feared that hot water developed by the hole would interfere with crosscutting. This fear proved to be justified.

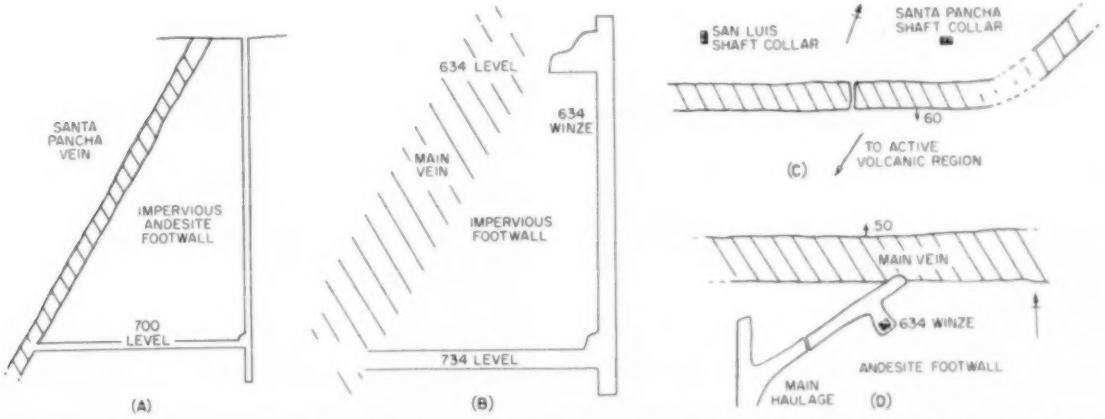
Each round on the 700 level was drilled with caution to avoid sudden inflow of water. No values were found and the inflow of water did not exceed 40 gpm until 65 ft of vein had been exposed. Drilling at this point brought forth no water, but when the round was blasted it yielded an estimated 550 gpm at 162°F, and this subsequently increased to 166°F. The quantity of water in itself was not too great a problem (the sister mine, La India, was at that time draining 10,000 gpm through its San Lucas tunnel), but water only 46° below the boiling point presented special difficulties that proved impossible to cope with at the time, and the shaft flooded almost immediately to within 80 ft of the collar.

Tests of water inflow were performed using an air lift pump for draw-down. Upon completion of these tests, a special deep well pump was installed. This lowered the water table and enabled mine production to proceed from an adjacent shallow shaft.

Origin of Hot Water: The origin of this water is a matter of some speculation; whether it is of magmatic or meteoric birth is difficult to say, but, undoubtedly, it owes its high temperature to the nearby volcanoes. At San Jacinto, at the base of the Cordillera near Cerro Negro, a hot water spring yields water at 200°F and a hole drilled to explore its floor yielded steam under pressure. A strong odor of hydrogen sulfide is present and a qualitative analysis showed traces of boron and fluorine. A corrosion test of a sample of the Santa Francisca water showed it to be high in sodium and calcium sulfates. Further qualitative tests at the site established a pH of five and the presence of boron, carbon monoxide, and hydrogen sulfide.

Two features which point to waters of deep-seated origin are the presence of hydrogen sulfide, especially since mining in this area has shown little if any sulfides from which it might have originated, and the presence of boron and carbon monoxide. It is believed that the 166°F water is a mixture of magmatic and meteoric waters, and further pumping, combined with chemical analysis, is expected to confirm this.

Indebtedness is due F. Kettel, General Manager, Empresa Minera de Nicaragua, for permission to publish this paper, to C. Almazan for his helpful suggestions, and to members of the Limon mine staff.



(A) Santa Pancha shaft and 700 level. (B) Winze and 734-level crosscut. (C) Santa Francisca shaft. (D) 634 level.

ARCTIC SURVIVAL STUDY:

ICE TUNNELING IN GREENLAND

Modern mining equipment has been found adaptable to a unique ice mining operation in northwestern Greenland. Part of a research program on arctic survival by the military, the operation has posed a series of new tunneling problems. Tools so far have ranged from black powder to continuous coal mining machines.

by JOHN F. ABEL, JOHN F. SULZBACH, and DONALD K. WALKER

Coal cutter used in 1957 operation. Electric drill and steel augers were used to drill cut block for blasting.

With the increasing military significance of the arctic, the U.S. Army Corps of Engineers' ice-tunneling research program has been instituted to determine the feasibility of excavating large under-ice openings. Such openings would provide for year-around storage of material and housing of personnel, independent of surface weather conditions. This unique ice mining operation has been carried on in the tunnels at Camp Tuto, Greenland, during the summers of 1955, 1956, 1957 and 1958 by the U.S. Army Snow, Ice, and Permafrost Research Establishment (USA SIPRE), Wilmette, Ill.

Supervisory personnel for the tunneling projects principally have been civilian mining engineers and mining engineering students from Colorado School of Mines. They have been employed under contract between USA SIPRE and the Denver Research Institute (DRI) of the University of Denver, Denver, Colo. Laborers have been enlisted military personnel attached to the U.S. Army Polar Research & Development Center (USA PR&DC), Ft. Belvoir, Va.

Camp Tuto is a summer season installation, operated by USA PR&DC, and located 16 miles from Thule Air Force Base in northwestern Greenland. This area is roughly 700 miles from the north pole, features permafrost to a depth of 1000 ft, and enjoys an average yearly temperature of +8°F. So far,

J. F. ABEL is Mining Engineer with USA SIPRE, Wilmette, Ill. J. F. SULZBACH, Mining Engineer, and D. K. WALKER, Mining Engineer, served with USA PR&DC in 1958 and will be under civilian contract with DRI in 1959.

Entrance to 24 x 100-ft room in 1957 tunnel. Note horizontal silt bands in ribs. Coal cutter is at face, left

Tunnel face after blasting. Large fragmentation was desirable for hand loading employed in the 1957 operation.

operations have been confined to the months of June, July, and August, when the temperatures range from 20 to 50°F, 24 hr of daylight are available, and down time due to weather conditions is minimal. Logistics is a problem, as the sea shipping routes are open only nine weeks in late summer; at other times men and supplies must be flown in.

In the Camp Tuto area, the ice cap terminus varies from a gentle, moraine-free ramp, through steep moraine-covered slopes, to a very steep cliff face on the shore of Lake Tuto. In choosing a tunnel site, factors considered were: accessibility, seasonal surface melt (about 4 ft of vertical loss per year), and location of morainal-debris bands.

In June of 1955, a dirt fill access road and pad were built on the ice. Tunneling operations were begun at the base of the 110-ft ice cliff, where maximum overburden depths could be reached with minimum face advance. Daily work was confined to one 8-hr shift of 9 men. The ice was broken by hand with steuri picks (single-pointed), shoveled into plastic boat sleds, and dragged out to the portal and dumped. Two men handled each of the above phases, and rotated jobs every 30 min to relieve fatigue from the arduous picking operation. The picking technique consisted of undercutting the face, then slabbing to the undercut.

During the season, 500 ft of 5½ x 6½-ft tunnel was driven at an average advance of 12 ft per shift. A 50-ft side drift, of the same cross section, and a 10 x 20-ft room, 6½ ft high, were also mined, removing a total of 860 yd (in place). Problems adding to the over-all inefficiency of this operation were meltwater flooding of the portal, rock debris bands (old terminal moraines) within the ice, and the increasing difficulty of picking ice from a face under heavy overburden pressure.

In 1956, work was continued on the 1955 tunnel. Thirty-one men were employed on a three-shifts-per-day basis. Ice was broken by a sawing-picking method using a two-man chain saw with a 3-ft blade. Vertical relief cuts were made in the face, followed by picking to advance and trim the face. Mucking and haulage continued by the primitive shoveling and boat sled method but, eventually, rail arrived and hand-tramming with 18-cu ft cars was instituted.

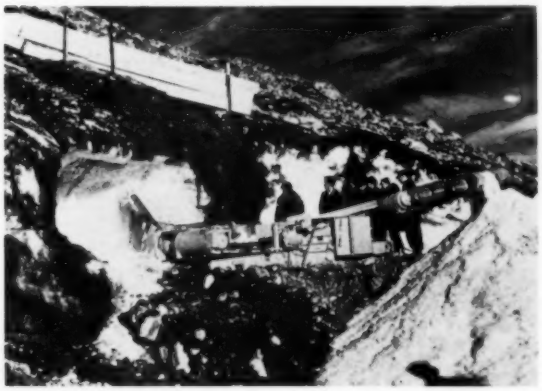
A 60 x 60-ft room, 20 ft high, was first excavated. A 20-ft raise was driven from an entry cross cut; then 9 x 7-ft drifts were extended to partially outline the four room pillars, and successively lowered until the room height was 20 ft. These pillars were subsequently blasted with black powder, at a consumption of 0.40 lb of powder per yd of ice broken. Since the roof was badly shattered and was subject to later roof falls, it was decided that safe openings could not be made through blasting methods. In addition to the room, the main tunnel was enlarged to 6½ x 7½ ft and extended 625 ft, for a season's total of 3300 yd (in place) removed.

In 1957, work was continued by two 10-hr shifts per day. A Joy 10-RU universal coal cutter was employed in an attempt to mine large openings which would not be subject to roof failure. This method proved entirely successful in the excavation of two 7½-ft high rooms: one 32 x 100 ft, the other 24 x 100 ft. The procedure generally followed was to cut the periphery of the face with the coal cutter, and then to drill and blast the cut block. Optimum (large) fragmentation resulted from using 0.06 lb of black powder per cu yd of ice broken. The broken ice was hand-loaded into 18-cu ft cars and trammed out with a 1½-ton battery locomotive. The existing tunnel was also enlarged to 12 x 7½ ft, and extended to a length of 1167 ft. To date, no failure has occurred in openings cut with the coal cutter. A total of 5070 yd (in place) were removed in 1957.

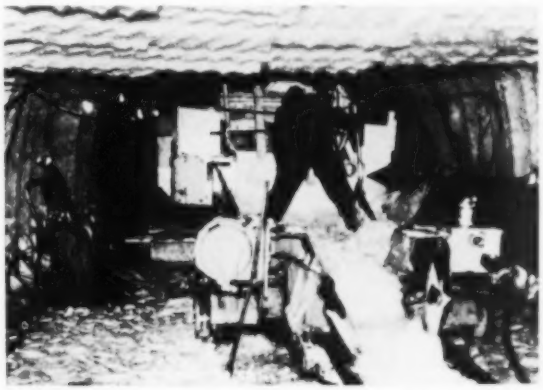
The coal cutter operated very satisfactorily in ice free of debris, and could cut with difficulty ice containing silt and fine sand; but it could not cut through bands of ice containing rocks or pebbles. If a cutter bit struck a pebble squarely, the rotation of the cutter chain was stopped. Hand picking was necessary to get through such areas. The material in these debris bands has been investigated. The rock particles, derived from a granite gneiss, range in size from 4 cu ft to −325 mesh.

At overburden depths to 200 ft, ice was flowing into the tunnel and rooms at rates as high as 3 ft of vertical closure per year. To minimize closure effects it was decided to start a new tunnel in 1958, at a higher elevation in the moraine-covered ice. Modern high-capacity equipment was to be used in an attempt to mine a prototype under-ice installation.

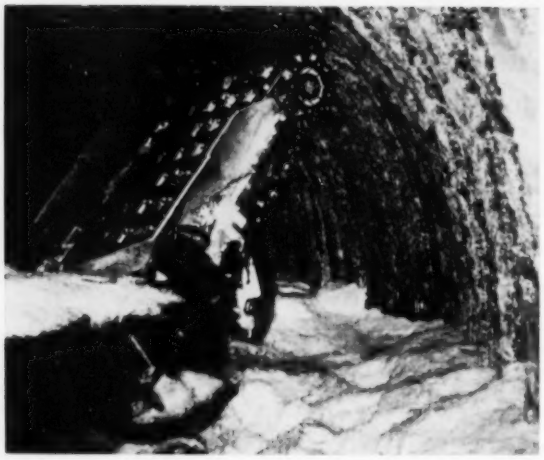
In 1958, a crew of 7 civilians and 20 enlisted men worked on the new upper tunnel during two 12-hr shifts per day. Work consisted of 200 ft of 17 x 15-ft tunnel; 200 ft of transition ramp, 17 ft wide, at 4 pct grade; 700 ft of 17 x 7½-ft tunnel; 11 room-necks; and 2½ rooms. One room is 30 x 200 ft, the other is 36 x 200 ft, both 7½ ft high. The partial



Joy 3-JCM continuous miner starting 1958 upper tunnel. Note rock-deflecting barrier, thinness of the moraine.



Operator cleared belt-jamming overloads from shuttle car. Oxy-acetylene equipment, left, melted ice build-ups.



Troublesome fines were produced by miner cutting head.

room measures 18 x 100 ft, 7½ ft high. Total ice removed amounted to 12,130 yd (in place).

Power source was a 300 kw, 440 v, 60 cycle, a-c diesel generator, installed on the dirt-fill pad at the portal. Voltage was transformed to 4160 v for transmission to the working area, where it was reduced to 440 v. Ventilation was by blower fan through collapsible vent tube. A timbered portal, 15 x 10 ft and 20 ft long, protected personnel from rolling rocks thawed from the moraine slope, and compensated for the ablation of the portal over the summer.

Actual mining was done with a Joy 3-JCM continuous miner, which discharged onto a 24-in. bridge conveyor, and from it to the tailpiece of a Joy 30-in. extensible belt conveyor. At the portal, the belt discharged to an elevating conveyor which stacked cuttings on the dump. A bulldozer periodically leveled the dump. This cycle was used to complete the first tunnel cut of 17 x 7½ ft to its full length of 1100 ft. At times, advance was as great as 10 ft per hr.

On retreating to the portal for the second 7½-ft cut, six roomnecks on the right side were cut. The second tunnel pass consisted of enlarging the first 200 ft to a full 15 ft high, and then sloping up at 4 pct for 200 ft to form a transition ramp. Following this, the five roomnecks on the left side were driven.

Since the bridge conveyor broke down while cutting the left-side roomnecks, it was necessary to improvise a new muck-handling cycle. The miner discharged in front of a Joy 8 BU gathering arm loader, which then filled a Joy 60-D shuttle car which transported the muck to the tailpiece of the extensible belt. Independent of the miner (without the connecting bridge conveyor) the belt tailpiece had insufficient traction to move ahead and still maintain proper belt tension. Therefore, it was snubbed, by chains, to deadmen in the floor, and moved ahead in 50-ft increments. The loader actually served as nothing more than an elevating extension of the miner, since the miner tailpiece could not elevate high enough to efficiently load the shuttle car. Originally, the loader had been planned for use in conjunction with the coal cutter, but it was down with a burned-out cutting motor.

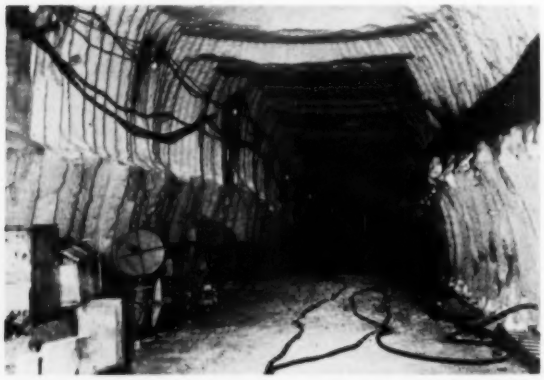
Considerable difficulty was encountered in applying coal mining machinery to ice excavation. Some of these problems were overcome by field modification, while others were constantly recurring sources of delay. Short pieces of track spikes were welded to the pads of all crawler-mounted equipment to increase traction. A timber ramp was constructed in front of the conveyor tail piece so the shuttle car could drive up and discharge efficiently. A swinging gate on the shuttle car served to control sudden discharge overloads which had been stalling the short, integral belt of the conveyor tailpiece. Hopper-like sideplates were welded to the tail piece to further reduce spillage, and facilitate faster discharge of the shuttle car.

By far the worst unsolved problem was the infiltration and subsequent consolidation of fine ice particles on critical moving parts. Ice build-up under ripper chains of the miner caused the chains to ride up out of their tracks and eventually stall the cutting head. Fines also built up on the rollers and idlers of the tailpiece integral belt, until the belt stalled and jammed. The only solution was to periodically remove the ice, usually with a heating torch. In 1959, it is proposed to try a variety of strip and radiant heaters in an effort to control this problem.

Line and grade were maintained using grade chains set on an offset drive line. Survey stations were spads in ¾-in. dowels set in the roof. Both surface and underground surveying were complicated by the absence of an absolute reference benchmark, since the ice was always melting and moving. A point near the face of the lower tunnel was considered relatively stable, and was used as a benchmark. Under maximum overburden of 150 ft, closure in the large rooms in the upper tunnel was indicated to be less than 2 ft per year. Such a rate is compatible with plans for periodic re-excavation of such installations.

In 1959, the upper tunnel will be completed, and will consist of four large rooms, and 1100 ft of 17 x 15-ft tunnel. Also in 1959, a tunnel will be driven in the permafrost of the terminal moraine, using various drilling and blasting techniques.

Although these operations have been inherently inefficient, and plagued with difficulty, they have shown the possibility of adapting modern mining equipment for military arctic construction.



Second-pass portion of 17 x 15-ft tunnel carved in 1958.

Acknowledgements are gratefully made to Dr. Henri Bader, Chief Scientist; Mr. W. E. Boyd, Chief, Applied Research Branch; and Mr. James Hicks, Acting Chief, Coordination and Publications Branch; all of USA SIPRE, Wilmette, Ill.

THE COPPER PROVINCE OF THE SOUTHWEST

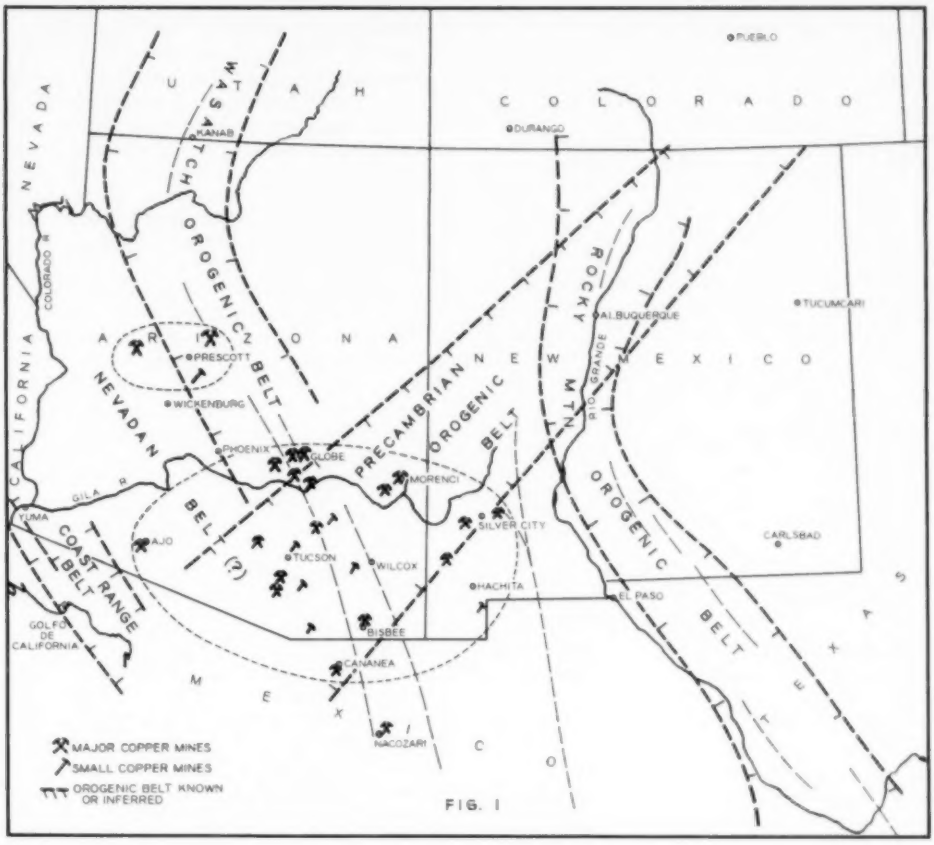


FIG. 1

by **HARRISON A. SCHMITT**

One of the great copper-producing areas of the world is comprised of five U. S. western states and northern Sonora, Mexico. The Southwest province of this area, covering southern Arizona, southwestern New Mexico, and northern Sonora, produces some 55 pct of U. S. copper output and the equivalent of 15 pct of world production. In 1956 the area produced about 550,000 tons.

Tucson is approximately the center of the oval-shaped province, which measures only 300 miles on its east-west axis and about 200 miles on its short axis. Northwest of the oval, and forming a tenuous connection with the Utah and Nevada copper fields, is an important operating mine, Bagdad, and also the now inactive United Verde. Along its north-south axis, running from Globe, through Tucson, to Nogales, ten moderate to major copper properties have been discovered or revived during the past 15 years, and five of these in only the past seven years. The latter five properties lie in an area 25 miles in diameter, centering 20 miles south of Tucson. In order of discovery, or revival, they are: Banner's Mineral Hill and Daisy; Cyprus et al's Pima; Duval's Esperanza; Asarco's East Pima (now called Mission mine); and Lewisohn's Peach. Total tonnage is estimated at about 250 million tons averaging some 0.90 pct Cu, but ultimate production may exceed this amount since some of the reserve is *open ended*.

Total positive and probable reserves of the Arizona-New Mexico-Sonora area is roughly estimated at 2.5 billion tons, averaging about 0.80 pct Cu. This amounts to about 17.5 million tons of recoverable copper, equivalent to about 12 year's supply at present U. S. rate of consumption. This tonnage should last about 35 years at the area's present rate of production. The reserve, in addition, includes important amounts of associated molybdenum, gold, and silver, as well as potentially valuable sulfur.

Possibilities for further extensions of known reserves are good. Arizona tax laws discourage development of reserves beyond those needed for planning, so present estimates are likely to be conservative. Also, use of geological and geophysical techniques surely will result in additional new discoveries. Even now at least one new very large low grade deposit is under drilling development. Moreover, more and more *protore* becomes ore by definition as improvement of exploration and exploitation methods results in lower costs. At active mines, marginal and lower grades of ore have a

H. A. SCHMITT is Consulting Mining Geologist, Silver City, N. M., and Tucson, and Consultant and Manager, exploration department, Duval Sulphur & Potash Co., Copper Div., Tucson.

great advantage: much of the stripping is done and the plant is built. These considerations suggest that an estimate of double the present indicated reserve is not extreme. This would result in a 70-year life for the area at present rate of production.

MINES OF THE PROVINCE

Christmas Mine: The Christmas mine, ten miles north of Hayden, Ariz., has had a long and varied history. For about a decade and a half, from 1935 on, Christmas Copper Co. and Sam Knight Leasing Co. almost continuously produced low grade copper ore for flux for the Hayden smelter. During this period, through the persistence of the Knight brothers and continued geological work[5], a new high grade orebody was found on the north contact. USGS and USBM greatly aided the development by several programs of study and by diamond drilling. Cyprus Copper Co. also did some moderately successful drilling.

In 1953 Allison Steel Co. leased the property, but after rehabilitating the mill they assigned the lease and option to Anaconda Co. Extensive geological work and drilling then disclosed many millions of tons of medium and high grade ore, laterally and in depth. The mine is now acknowledged to be one of the important underground copper mines in the Southwest.

The orebodies are at least spatially related to a pluglike diorite porphyry. This has dikelike apophyses that intrude Paleozoic limestone, shale, and quartzite and Cretaceous (Colorado) andesite in the area of the intersection of a northeast fault and shear zone with a major northwest fault. Early mining, which started around 1905, was in Pennsylvanian limestone and shale. Mining became more or less stalled at the base of this series on the 770-ft level during the depression of the 1930s. Then, beginning about 1940, the higher grade ore in the Mississippian series was discovered, developed, and mined on the northwest contact of the plug below the 770 level.

San Manuel: The San Manuel mine was developed by churn drilling, starting from a small outcrop of oxidized copper minerals. Imaginative geological surmise by several individuals was responsible for the final success of the enterprise. The Bureau of Mines, after recommendation by USGS, did some of the early drilling. This deposit, which is of the porphyry type, has been described by Schwartz[15], Pelletier[7], and others. The wall rock is largely quartz monzonite (oligoclase granite), quartz monzonite porphyry, and diabase. The orebody is localized along a northeast-bearing fault zone in the form of a great upright *U* that strikes northeast. Mining is by block caving.

Pima: The Pima orebody, about 20 miles south of Tucson, was found following a well-planned search of local mineral occurrences by geologists and engineers of United Geophysical Co. and by their regional geological work. The orebody was delineated by geophysical methods. Now mined by open pit, the ore was covered by 200 ft of gravel. The orebody lies in a brecciated block of ground, above a major fault that dips about 45° south. Host rocks include Permian limestone and quartzite and Cretaceous (?) arkose and subgraywacke. The primary ore mineral is chalcopyrite. Primary gangue minerals include magnetite, pyrite, garnet, clay, serpentine, and minor quartz. Some of the gangue is unreplaced limestone.

Mineral Hill, Plumed Knight, and Daisy: Banner's Mineral Hill, Plumed Knight, and Daisy groups of orebodies were revived or discovered and developed largely through the imaginative drive of A. Bowman, Jr., the present manager. Geological inference and magnetometer work pinpointed most of the new orebodies. Mining is done underground.

The Daisy and Mineral Hill mines are just west of the Pima. The Pima ore zone crosses its mutual property line with Banner. Daisy mine ore mineralization, which is similar in most respects to the Pima, is localized in part in the hanging wall of the Pima footwall fault. This fault, after a substantial throw to the south by a north-south vertical fault (tear?), continues westward. It forms the footwall of the Plumed Knight ore zone and then, farther west, the footwall of the Mineral Hill orebodies. Coarse granitoid rock, including oligoclase granite, intrudes the Mineral Hill mine area and is accompanied by a pegmatitic facies.

The Twin Buttes east extension, about seven miles south of Mineral Hill, is another property acquired and developed by Banner Mining Co. It was discovered by magnetic work and diamond drilling on the extension of a normal fault contact between an oligoclase (?) granite and limestone. The contact had produced the ore of the district in the past. The ore is associated with pyrometasomatism.

East Pima: American Smelting & Refining Co.'s East Pima mine, north of Pima and east of Banner, was discovered and expanded by diamond drilling. Conflicting stories are current as to just how the discovery was made, but it appears to be an important find. According to a public report by Asarco, developed tonnage exceeds 65 million tons of 0.9 pct Cu. Presumably it will be an open pit mine. Not much has been revealed about the geology but the ore is associated with limestone, subgraywacke, etc., and there are blocks showing pyrometasomatism. The ore appears to be localized, at least in part, in Paleozoic limestone and in the Cretaceous (?) clastic series. Banner geologists believe that there is a major flat thrust fault in the area. The ground is intensely broken and is marked by complicated structural features.

Silver Bell: The geology of another Asarco property, the Silver Bell mine, has been described by Richard and Courtwright.[9] One of the two orebodies is in monzonite and dacite porphyry; the other is in alaskite and monzonite porphyry. Both appear to be localized by the intersection of northeast fractures with a major northwest structural zone.

Esperanza: Another recent discovery, the Esperanza of Duval Sulphur & Potash Co., about four miles southwest of Twin Buttes and 28 miles south of Tucson, has been reported to contain more than 50 million tons, with important molybdenum values. Gold and silver content is low. The ore is localized in the Cretaceous (?) clastic series, mostly arkose and subgraywacke, in intrusive quartz monzonite (oligoclase granite) with porphyritic apophyses, and in intrusive andesite. The oligoclase granite has an associated pegmatitic facies. Syenite and a dike of nepheline syenite have been identified. A strong flat south-dipping fault is at the base of at least part of the orebody. The orebody has been intensely brecciated—it resembles a mass of weakly-coherent rubble—and the primary mineralization is composed of quartz, clay minerals, biotite, chalcopyrite, molybdenite, and minor pyrite. The orebody is

marked by an unusually regular chalcocite-enriched blanket with a capping of about the same thickness, but the protore is rich enough in places to constitute ore, especially since it has a good molybdenum content. Oxidation is minor. Exploitation will be by open pit, with much of the ore above the level of the concentrator's primary crusher.

The orebody was found by geological work, which outlined the favorable ground on the basis of limonite capping, ground preparation (i.e., largely brecciation); alteration effects, such as clay, sericite and quartz veins; and copper staining. As now developed, the orebody closely corresponds to the geological anomaly originally mapped. Detailed geological work has been done by past and present company geologists Clippinger, Roper, Schmitt, and Toombs.[10] Original reconnaissance, capping study, and petrographical studies were made by Schmitt. The ore overlaps the contact of a regional oligoclase granite pluton. Southeast bearing porphyry apophyses extend through the orebody, and, in the area of the orebody, these are cut by northeast faults and fissures. Much irregularly intruded andesite porphyry is largely localized in the orebody area. The wall rocks have been greatly deformed at the granite contact where some of the clastic beds stand on end.

Peach: The mining and development at Helvetia, Ariz., that turned up the Peach orebody are the result of the enthusiasm and drive of R. Chilson, president of Lewisohn Copper Co. The orebody lies in the upper plate of a nearly flat thrust, originally described by Schrader.[16] Oligoclase granite predominates below the thrust. The upper plate is composed of steeply dipping Paleozoic quartzite, limestone, and shale intruded by porphyry. The orebody is in intensely-brecciated sedimentary rock that lies above the thrust fault, east of a strike fault, and north of a dip fault. Garnet and diopside are common gangue minerals. Ore minerals include pyrite and chalcopyrite. Chalcocite enrichment is largely absent. Some of the ore developed to date is moderately oxidized. Geologist A. Hymen did most of the recent detailed geological work.[8] Original capping work and outline of the favorable alteration was done by Schmitt.

The Peach orebody was discovered by drilling another geological anomaly. The area selected as favorable had been moderately mined in the past. It is marked by favorable capping, copper staining, pyrometasomatic alteration, and intense becciation. Drilling to date has largely confirmed the predetermined anomaly.

GENERAL ASPECTS

All of the ore deposits described are closely associated with intrusive igneous rocks, but all are also closely associated with one or more large or *master* faults. This reminds us that certain Canadian geologists for some time have emphasized the predominant role of the master fault or faults in localization. The writer suggested this view in 1933.[11] Such a fault or faults are associated with the Bisbee, Christmas, United Verde, Ray, Tyrone, Bagdad, San Manuel, and Miami orebodies; large faults, particularly the Copper Mountain, are characteristic at Morenci. Some of these faults apparently coincide with or are associated with geosutures of continental scope that appear to be associated with most of the major copper deposits in the Southwest.[12]

Situated in the Twin Buttes-Mineral Hill area is a basement of pre-Cambrian granite with overlying Paleozoic quartzite, limestone, shale and minor gypsum beds, and Cretaceous (?) clastic beds and volcanic rocks. This terrain has been intruded by Tertiary (?) oligoclase granite which extends in area about like the pre-Cambrian granite. The pre-Cambrian granite predominates in the northwest part of the area, the Tertiary (?) in the south part.

Where the oligoclase granite is intrusive into the limestones, copper-bearing skarn masses are developed, and in places are associated with a pegmatitic facies. All of the ore zones, except possibly the East Pima, lie largely in the hanging walls of east-west faults that dip on an average of 45° south. Presence of nearly flat thrusts in the East Pima area have been suggested by Banner Mining Co. geologists. There are a few known north-south high angle faults, probably of the tear type. The one at the Daisy mine has horizontal striations.

Several of the east-west south-dipping faults are thought to be thrusts. G. W. Irwin[4] reports a complicated arcuate thrust system at the San Xavier mine and E. Stone[16] reports east-west thrusts throughout the area. The writer believes the Twin Buttes mine's east-west major fault is normal.

In the northeast part of the area, granite is encountered at various depths and in one case has the appearance of a sill-like mass. Stone thinks the region is marked by a flat thrust that dips eastward.

The combined opinion of men who have done much recent work in the area suggests the following sequence of events in Tertiary time: 1) Flat thrusting; 2) Intrusion of oligoclase granite; 3) Thrusting from the south, expressed largely by east-west faults dipping flatly south and accompanied by largely north-south tear faults; 4) Some normal faulting; 5) Ore mineralization.

The ore is localized at Mineral Hill by the east-west, south-dipping lode and the intersection of flat faults,[8] and at the Pima mine by an east-west, south-dipping lode (and flat thrust faults?) The East Pima area is characterized by complex faulting and intense brecciation. At the San Xavier lead-zinc-silver property, the ore is localized as chimneys at the intersection of south dipping thrusts and north-south tears[4].

Where host rocks contain limestone the ore is pyrometasomatic, usually accompanied by magnetite, garnet, and other silicates. This provides targets for magnetometer work, which has been unusually successful in this district. Where the walls lack limestone the iron in the original rocks is largely captured in pyrite, chalcopyrite, chlorite, and epidote. This, theoretically, should result in negative magnetic anomalies where the original host rocks, such as igneous rocks and graywacke, contained magnetite; and it suggests that magnetic lows may be about as interesting as the magnetic highs. The magnitude of local magnetic contrasts is an important factor. It is difficult to closely pinpoint pyrite-chalcopyrite orebodies that commonly occur in wall rocks other than limestone because there is usually a wide, irregular peripheral zone of the very low grade copper and pyrite. This zone at the Esperanza mine is about ten times as large as the area of the orebody.

Thick sections of graywacke, subgraywacke, arkose, conglomerates, agglomerates, and other clastics, as well as younger (?) volcanic breccias, occur

along the Mineral Hill-Esperanza axis. These rocks have been designated Lower Cretaceous. Some of the subgraywacke could be classified as fine-grained quartzite or novaculate, but subgraywacke may be the best general term. Much of the Esperanza ore and the ore in the Pima and North Pima area occurs in this rock section.

As noted, mines in the Mineral Hill, Twin Buttes, Esperanza, and Helvetia areas have abundant skarn minerals including garnet, pyroxene, actinolite, epidote and magnetite. Other minerals include biotite, chlorite, pyrite, chalcopyrite, sphalerite, galena, and oxidized or secondary copper, zinc, and lead minerals. Clay minerals, largely of the kaolin and montmorillonite groups also appear to be present.

Some three decades ago, the labeling of an ore deposit as contact metamorphic (equivalent to the present, more accurate term contact pyrometasomatic) was the kiss of death to possible mining. Such deposits were considered to be too low grade and erratic to be of commercial value. Note, however, that the Christmas, the mines in the Pima area, Twin Buttes, and Helvetia belong to the above classification. Bisbee is a *low grade* metamorphic member of the class. One wonders to what extent the development of worthy properties is delayed by current fashion and opinion. It now can be seen that the prejudice had neither a scientific nor an engineering basis.

It also should be noted that many of the so-called disseminated copper deposits are largely, or importantly, primary or hypogene-enriched, not supergene-enriched. Deposits of the Pima and Helvetia areas fall in the hypogene class and the deposits of Ajo, Ariz.; Madanpeck, Yugoslavia; and Toquepala, Peru, also wholly or substantially belong to this class.

The reasons for localization of a major copper province or sub-province in a relatively small area in Arizona has long been a subject for speculation and contention. In addition to copper deposits, the area is marked by a notable concentration of active, or formerly active, lead, zinc, silver and silver-gold mines. Igneous activity and deformation of the crust since pre-Cambrian time appear to have been strong; results of these phenomena appear to diminish north of Globe, Ariz., and east of Hillsboro, N. M., but the area is probably open ended, in this respect, southeast of Cananea, Mexico. West of Ajo, observational data are deficient, except that northwest of the *oval* there is a tenuous extension of copper mineralization, mining areas noted for metals other than copper, and an expression of strong igneous and deformational activity. The northwest striking arcuate mineral belt from Santa Rita, N. M., to Bagdad, Ariz., is part of Butler's Plateau mineralization arc.

An objective view of possible broad genesis is handicapped by the fact that geology of mining districts is more closely studied than the surrounding areas.

The area in question is known to be a greatly disturbed and modified section of the crust. Few of the mountain ranges lack strongly-folded rocks, normal and thrust faults, and various igneous phenomena. The thrusting appears to come from all points of the compass, although perhaps that from the southwest predominates. There is a conspicuous lack of it from the northwest. Southwest thrusting is normal to the continental coast line to the southwest, and normal to the trend of the mountain ranges in southeastern Arizona or most of southern Arizona. It presumably represents the late Jurassic, i.e., Nevadan orogeny, plus an unknown superposition of late (?) Miocene and possibly earlier Tertiary deformation.

In New Mexico this northwest orogeny may extend as far east as Santa Rita. East of Santa Rita, north-south Rocky Mountain orogeny dominates as far east as the Tularosa basin. Associated with this later orogenic belt is normal thrusting. Here, the mountain ranges also dominantly trend north-south.

In southeastern Arizona and southwestern New Mexico, the ore bearing veins, fissures, and dikes have a preferred northeast trend. Northwest and north trends are less common, and, except near the Mexican border, east-west trends are rare. Observations on the pre-Cambrian schistosity throughout this area indicate predominating northeast strikes; more rarely north-south. There may be a causal relationship between this schistosity, widely buried by thick sections of later rocks, and the trend of post-Cambrian veins, dikes, etc. This schistosity may represent a pre-Cambrian orogenic belt, as has been commented on by Billingsley and Locke, Wilson, and others.

Whether or not the concentration of orogenic trends and intersections in this copper province is unique and favorable to copper precipitation has been debated for a long time.

The accretion theory of the earth's origin, again popular, suggests that infall of planetesimals high in copper could have resulted in the localization of this province as well as others. This is supported by the fact that the copper mineralization in the Southwest is apparently of several widely-separated ages. The theory, however, probably would not account for the impressive localization of strong crustal disturbance and igneous activity.

The especially intense, older pre-Cambrian orogeny and igneous activity regionally may have localized metallization, especially copper. From then on the metals, when activated by recurrent orogeny and igneous activity, leaked through the faults and fissures that persistently broke through the younger rocks along the northeast direction of crustal weakness. None of the later orogenies appear to have been as intense as the older pre-Cambrian (Wilson's Matzatzal).

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EXTRUSION-AGGLOMERATION OF IRON FINES

Problem in agglomerating or briquetting ferrous fines? Try the continuous pugmill-extruder.

by IRA A. STARK

Use of clay-working machinery in the metallurgical industry is by no means new. Extrusion-agglomeration as a basic operation in the non-ferrous field has a history of more than 50 years. This article advocates using the technique in the ferrous field where it might serve a useful purpose in today's operations.

Many of the processes involved in production of iron ores result in fine powders, with a considerable percentage running finer than 200 mesh. In many instances, mining and related processing operations are located far from furnace operations. Shipping the powdered ore is impractical since handling losses and furnace losses from dusting would be excessive and powdered material must be agglomerated. The agglomerate must withstand the handling involved in transportation and here the continuous pugmill-extruder can be used to form a strong dense product.

The extruder has been used for many years in the ceramic industries to temper earthy materials with water, the resultant plastic mass being extruded in the form of brick, sewer pipe, etc. The physical handling of the product between the extrusion and the firing process, as well as the firing process itself, demands a strong dense extrusion column. Extremely high temperatures are encountered in the firing kiln and a small air bubble in the unfired article would expand and cause distortion. For this reason, the vacuum section of the pugmill-extruder is important. Considerable pugging as well as extrusion takes place under vacuum.

Relatively non-plastic minerals such as finely divided ores, manganese dioxide, and fluorspar can be made plastic enough to benefit from the extrusion-agglomeration process. This can be done by adding small percentages of such materials as bentonite and lignin in the pugging section along with the tempering water. In the ceramic field, non-plastics such as alumina are rendered extrudable by making these additions, and pugmill-extruders are used to form alumina refractories and metalloids such as ferrites. Since the extruded column of iron ore would be a solid cylinder of large diameter (about 5 in.), there would be much less die resistance than in the case of hollow tile or sewer pipe. This feature would eliminate the need for very high plasticity. Such an extruded column can be cut with a conventional automatic wire cutter into sizes suitable for handling and shipping.

Binder material must be well pugged into the mass of powdered ore and its selection is highly important. Many inexpensive byproducts such as sulfite liquor and bitumen have proved useful in producing a strong, adhesive extrusion. Any pugmill additions must be carefully selected with a view toward cost and effect on the product. Fluorspar, for example, must be as free of silica as possible. Certain grades of bentonite serve the dual purpose of rendering the pugged mass extrudable and the extruded column cohesive. A bentonite addition, therefore, must be carefully considered. Generally speaking, organic binders which coke and burn out in the blast furnace or open hearth are preferable to those which leave a residue. Certain mixtures are self binding and quite plastic within a reasonable working range. The coke-breeze and coal tar mixtures used in the Soderberg electrode process are a case in point.

Units of this type can be used for extrusion agglomeration of finely divided ore. Product is dense and strong, able to stand handling. Fine dust losses are eliminated.

Capital outlay and operating costs for extrusion-agglomeration are lower than those for a sintering operation. Sizes of available equipment range from laboratory units to machines that can produce 30 tph of agglomerate. The production target and flowsheet may call for one large extruder or a battery of medium-sized units.

Ceramic pugmill-extruders were built with relatively soft, plastic materials in mind. Technology involving ceramics other than soft clays has brought changes in equipment. The basic unit remains the same but materials of construction have been changed to include cast steel augers and all-welded construction. More powerful drives also have been incorporated into equipment destined to process ores.

Ceramic equipment is designed for long wear and it is not unusual to find equipment in operation for 30 or 40 years. Belt drives and sleeve bearings are well suited to the field conditions of the industry. Augers, pugknives, seal dies, extrusion dies, and liners must occasionally be replaced, depending upon abrasive conditions encountered, but properly selected machinery will give long and useful service.

I. A. STARK is Ceramic Engineer, International Clay Machinery Co., Dayton, Ohio.

X-RAY MINERAL ANALYSIS TECHNIQUES

A survey of applications of X-ray fluorescence analysis techniques to problems of exploration and mining. Emphasis is placed on rate, accuracy, and expense compared with conventional wet chemical methods.

by RALPH E. WOOD

X-ray fluorescence analysis can be profitably applied in the mineral industry by improving evaluation and control analyses, while offering lower cost and greater speed than conventional methods. Chemical analyses are not only a major item of cost in exploration and mining, as well as in milling and chemical treatment, but often cause evaluation and control of processing steps to lag behind operations.

In the fields of geology and mining, the X-ray technique can be employed without destroying samples and, if necessary, specimens can be analyzed and then used, unchanged, in other evaluation techniques. Results are quickly made available for decisions on progress of exploration or sorting of waste and ore.

In milling and chemical processing there is an additional advantage in possible automatic control of processing. Essentially instantaneous chemical assays can be obtained at desired points in the process stream and these measurements used to control the processing for desired metallurgical results. Individual components required for such control systems exist now but have yet to be integrated.

Research and production models of instruments capable of this X-ray fluorescence analysis, or X-ray spectroscopy, are available from General Electric X-Ray Dept., Milwaukee; North American Philips Co., Mount Vernon, N. Y.; and Applied Research Laboratories, Glendale, Calif. Each of these instruments has individual characteristics which may be of advantage in particular applications. With an increase of interest in X-ray analysis other companies are beginning to produce and market similar equipment.

Arrangement of Components: The fundamental geometric arrangement of components used in X-ray fluorescence instruments is shown in Fig. 1. The X-ray tube is of the high-intensity broad-range emission type commonly used in medical work but refined and adapted for analytical application.

The sample to be analyzed is placed close to the X-ray tube port. The sample may be in any shape or form: powder; solution; selected fragments of ore or rock; or metal filings, chips, rods, or sheet. Primary rays from the X-ray tube are absorbed by atoms of the sample and these re-emit X-rays characteristic of that atom. The secondary, or fluorescent, X-ray beam is collimated and then diffracted by a single crystal of LiF, NaCl, etc., which is mounted so that the incident angle and exit angle between the X-ray beam and the analyzing crystal are always equal. This geometrical requirement conforms with Bragg's law, $n\lambda = 2d \sin \theta$, which governs the process of X-ray diffraction by a crystalline material. In the above equation, n is the order of the particular diffraction and is always an integer; λ is the wavelength of the radiation being diffracted and is usually expressed in Angstrom units; d is the interplanar spacing of the analyzing crystal selected; and θ is the angle of incidence of the primary beam at the crystal face.

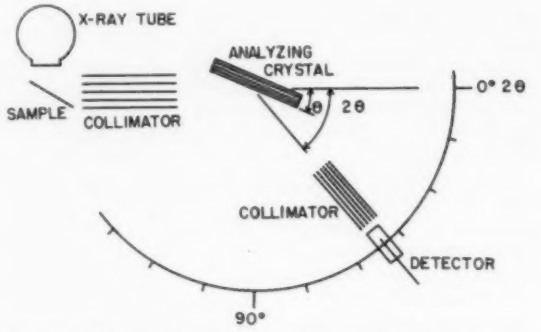


Fig. 1. Flat crystal reflection system. Diffracting wavelengths vary from 0.1 to 10.0 A to cover elements of atomic number 12 to 92.

The diffracted beam from the analyzing crystal is again collimated and brought to a detection device. The detection device is usually of the geiger counter type and is designed to be sensitive to radiation of the X-ray region.

The wavelength of radiation produced by atoms is a function of the atomic number of the atom. Elements of high atomic number produce short wavelengths or hard radiation. Short wavelengths will be found at low angular positions of the detector and long wavelengths at high angular positions. Therefore, the position of the detector depends upon the atomic number of the element producing the radiation and intensity of the radiation at that position is a measure of the concentration of the element in the specimen.

Qualitative analyses are obtained by moving the X-ray detector through all possible geometric angles progressively and recording the detector output. Typical results are represented by the curves on the chart shown in Fig. 2. This is a chart of a columbite sample and shows the presence of tin, columbium, zirconium, iron, manganese, yttrium, and tantalum. The element producing a given peak is found by referring to a standard table produced for the specific analyzing crystal used. Each element will ordinarily produce two to four lines on the chart and so a simple spectrum is obtained.

Fluorescent radiations produced by elements fall into a regular pattern with the wavelength decreasing as the atomic number of the element is increased. For elements of atomic number 12 to about 50, a series of emission lines known as the K

R. E. WOOD is Senior Scientist, Instrumental Analysis, Kennecott Research Center, Salt Lake City.

series is used. At about atomic number 50 the use of the K lines becomes impractical and the L series of lines is used. The two series cover the same range of wavelengths and there is some overlapping of lines. As an example, the second order of the principle zirconium line occurs at exactly the same angular position of the detector as the first order principle hafnium line. Therefore, the determination of hafnium in the presence of zirconium requires the use of one of the hafnium lines where there is no superposition.

The X-ray emission method of analysis can be applied to elements of atomic number 22 to 92 with no special apparatus. The group of elements having atomic number 12 to 22 can be analyzed by using both a helium path to avoid air absorption and a special analyzing crystal. Hence, any of the elements from magnesium to uranium (80 of the 92 occurring naturally) can be determined by X-ray methods if they are present in sufficient concentration. The lower limit for most elements is about 0.1 pct although many can be detected below this concentration. Special concentration steps are required for elements present in concentrations below 0.01 pct. A thorough presentation of the fundamentals of the X-ray fluorescence method was given by Birks et al. in 1953.[1]

X-ray technique can be very helpful for rapid assay of field samples where comparative results or indications are needed. For a quick estimate, intensities of any of the lines in the spectrum can be roughly related to concentration. Rapidly scanning the same angular area for a series of samples will allow comparison of elemental composition. Results of a series of rapid assays made on a group of exploration samples are presented in Table I. This estimate of concentration is used to screen samples so they can be assayed more accurately by colorimetric, gravimetric, spectroscopic, or other means, or eliminated from further assay work. Only 1 min was needed per assay and the results show the rapid estimates are accurate enough for many purposes.

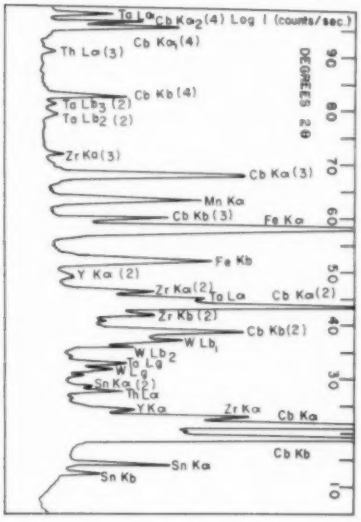
Table I. Comparison of Rapid X-Ray Estimates with Wet Chemical Assays on Same Material

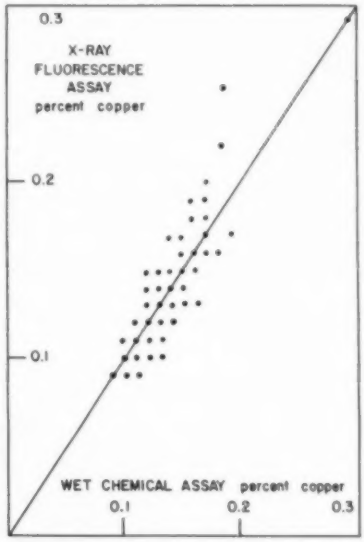
KRC Number	Ni, Pct		Cr, Pct	
	X-Ray	Wet Chemical	X-Ray	Wet Chemical
40665	1 to 2	0.63	0.1 to 0.5	0.38
40666	1 to 2	0.87	0.1 to 0.5	0.21
40667	1 to 2	0.63	1 to 2	1.77
40668	0.5 to 1.0	0.50	3 to 6	4.42
40669	0.4 to 0.6	0.25	1 to 2	1.18
40670	1 to 2	0.66	0.1 to 0.5	0.30
40671	0.1 to 0.2	0.15	0.1 to 0.5	0.30
40672	0.2 to 0.4	0.21	0.5 to 1.0	0.55

With the standard research model X-ray instrument, quantitative analyses are made by measuring the intensity of radiation produced by a given element and relating this to the intensity produced by known standards. For this reason the method is not considered an independent technique. The known standard samples may be either synthetically-prepared or chemically-analyzed materials, so long as they closely resemble the samples to be analyzed in form, particle size, surface texture, and approximate composition.

Sample comparison requires only a 2 to 3-min determination time and can be expected to yield accuracies of ± 10 pct of the amount present. This time includes sample preparation and data interpretation but excludes the time required to obtain the sample and reduce it to required size.

Further refinements of the method include fine grinding and the addition of an internal standard by grinding and mixing, by chemical solution and reprecipitation, or by fusion with a flux of low atomic number to yield a glass button. The internal standard technique will give accuracies of 1 to 2 pct of the amount present. Again the measurement time is only 2 to 3 min per determination. Data presented in Figs. 3 and 4 indicate the accuracy to be expected on routine ore or mill samples. The samples in Fig. 3 were taken from a pilot mill trial using ore from Kennecott's Ray Mines Div. The ore was being





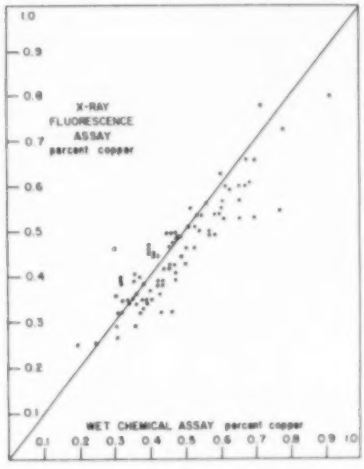


Fig. 2. (left) Qualitative chart of a columbite concentrate. Fig. 3. (center) Variation of X-ray fluorescence assay using Ray Mines Div. sand tailings samples. Graph shows a standard deviation of 0.024 pct Cu on 82 determinations. Fig. 4. (right) Variation of X-ray fluorescence assay using Ray Mines Div. slime tailings samples. Graph shows a standard deviation of 0.045 pct Cu on 108 determinations.

Table II. Bingham Toe Sample Assay Comparison by Standard and X-Ray Methods

Sample Number	True Assay Pct Cu	X-Ray A*	X-Ray B†
1	0.76	0.74	0.78
2	1.12	0.95	0.99
3	0.85	0.83	0.79
4	0.75	0.85	0.82
5	1.32	1.38	1.32
6	0.03	0.05	0.04
7	0.08	0.10	0.12
8	0.80	0.68	0.71
9	0.66	0.69	0.73
10	0.68	0.68	0.72
11	0.72	0.60	0.63
12	1.09	1.04	1.10
13	0.69	0.71	0.74
14	1.07	0.92	0.98
15	0.69	0.69	0.73
16	0.07	0.10	0.07
17	0.15	0.25	0.22
18	0.04	0.06	0.03
19	0.09	0.14	0.10
20	0.06	0.08	0.05
21	0.95	0.96	0.99
22	1.68	1.77	1.82
23	0.89	0.87	0.90
24	0.14	0.14	0.16
25	0.23	0.31	0.34
26	0.90	0.95	0.85
27	0.66	0.70	0.78
28	0.89	1.04	0.88
29	0.74	0.91	0.84
30	0.77	0.91	0.84
Standard deviation		0.082	0.066

* Assays without correction for variation in particle size.
† Assays with correction for variation in particle size.

treated by the leach-precipitation-flotation (L-P-F) process in an effort to improve copper recovery. Samples were taken at the end of each shift, dried, pulverized and mixed, and X-ray determinations were made at the start of the day shift. Assay results were available by 9 am and permitted process changes during the day shift. Comparison was made with wet chemical assays when these were available 8 to 24 hr later. The average X-ray assay is within ± 0.01 pct Cu (standard deviation of 0.024 pct Cu) of the wet chemical result. A similar comparison, made on the fine material which is separated and treated differently in the recovery process, is shown in Fig. 4. The greatest differences were always obtained during the first few shifts of a given trial, before an adequate instrument calibration had been completed. X-ray assays on these two types of samples required only 2 to 3 min each and averaged within 10 pct of the amount present.

For the analysis indicated in Figs. 3 and 4, samples were prepared by reducing representative portions to −100 mesh. These products were placed in leucite trays, ½ x ¾ x ⅛ in., and scraped smooth with a spatula. A General Electric XRD-3 instrument was used for the determinations and parameters were 50 kv peak potential and 40 ma tube current with a tungsten target AEG 50 Machlette X-ray tube. Fixed counts of 16,384 total impulses were used in each instance. The results of each day's assays were incorporated into the reference curve for analysis of the following day's samples.

One of the problems associated with the X-ray fluorescence analysis of ores is that for consistent results all samples must have about the same particle size. To illustrate this, a series of 30 samples taken from Kennecott's Bingham mine were studied. These samples have a particle size variation of from 0 to 45 pct + 200 mesh. The standard deviation of the X-ray results and wet chemical assays is 0.082 pct Cu. If these results are corrected for the variation in particle size, the standard deviation is 0.066 pct Cu, which is the variation to be expected if the samples are prepared with the same range of particle size. Correction of this data to a uniform particle size was carried out by restricting the samples to ranges of ± 5 pct + 200 mesh, that is, the range 0 to 10, 10 to 20, etc. + 200 mesh, and also by calculating the best curve for the group and determining the variation of each sample from its wet assay. The uncorrected and corrected data are presented in Table II, columns 3 and 4, respectively. Control of particle size within this narrow range is possible by careful control of the sample pulverizer. To obtain the data shown in Table II, one operator and one instrument analyzed at the rate of about 200 samples per 8-hr shift.

Cost Comparison: Comparison of the wet method vs the instrument method indicates that the X-ray assay will cost about half as much as the wet chemical analysis. For the type of assay indicated in Table II this amounts to 20 to 25¢ per determination for the instrumental analysis compared to 40 to 45¢ each for the wet chemical assays.

A refinement of the X-ray method, applicable to very small samples, i.e. about 0.1 mg in size, has been described by Adler and Axelrod[2]. It can be used for scanning polished sections of drill core or rock specimens. An even more elaborate instrument designed by Castaing[3] utilizes an electron beam for excitation and is capable of getting X-ray analyses on areas of micron size. Also, to show the fine limits that may be obtained with an ordinary instrument, Zemany et al.[4] have indicated how ion exchange techniques permit the X-ray determination of as little as 5 μg of potassium. Complex instruments capable of automatically making 22 to 25 element determinations sequentially[5] or simultaneously[6] on one specimen are available.

Summary: The X-ray fluorescence technique offers a simple, rapid, and efficient method of elemental analysis for both exploration and control work in the mining field. The method is nondestructive, which means that expensive drill core samples or polished sections may be chemical analyzed without loss or alteration. In the assay of mill products the technique reduces the lag time between sampling and assay, thus offering improved process control. Potentially, this technique offers a sensing organ for ultimate automation of ore milling processes. For many analytical applications, X-ray fluorescence offers reduction in assay expense and reduction in assay time.

The material presented in this paper is taken from instrumental analysis work done in assistance to many projects at Kennecott Research Center. The author expresses his appreciation to S. R. Zimmerley, director of research, who has encouraged the application of instrumental analysis, and to the management of Kennecott Copper Corp. for their permission to publish this data.

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ROCK BREAKAGE WITH CONFINED CONCENTRATED CHARGES

by WILBUR I. DUVALL and THOMAS C. ATCHISON

Over the past ten years a series of investigations have been conducted to determine some of the physical processes involved in breaking rock with confined concentrated charges. Detailed discussions of many of these investigations have been published elsewhere.[1-6]

Laboratory experiments made by other investigators using Hopkinson pressure-bar techniques have shown that solid materials are fractured in tension by the reflection of an incident compressive stress pulse at a free surface.[7-13] In these tests a small charge of explosive is placed in contact with one end of a bar. Detonation produces some plastic flow and crushing of the bar near the charge and generates a compressive stress pulse that travels along the length of the bar. At the free end of the bar the compressive stress pulse is reflected back into the bar as a tensile stress pulse. If the tensile strength of the bar is exceeded during this reflection process, a tensile fracture normal to the length of the bar is produced, and the broken end of the bar moves forward with a constant velocity equal to the average particle velocity trapped in the broken fragment. The new surface formed by the fracture becomes the new free end of the bar that reflects the remaining portion of the incident compressive stress pulse. This process is repeated any number of times until all of the incident stress pulse is reflected.

Hino has demonstrated this kind of breakage for three rock types—marble, granite, and sandstone.[6] He has defined a blastibility coefficient, B, as the ratio of compressive strength, C, to tensile strength, T, thus:

$$B = \frac{C}{T} \qquad [1]$$

The quantity B is the maximum number of slabs that can be produced by reflection breakage. Normally fewer slabs are produced because of loss of energy as the stress pulse travels through the rock.

Fig. 1 illustrates reflection-type fracture for a triangular compressive stress pulse. The number of slabs produced by the reflection breakage process is the first whole number less than the ratio of the peak stress of the incident pulse to the tensile breaking stress of the solid. Thus the number of slabs is given by

$$N = \frac{S}{T} = \frac{F}{2h}, \qquad [2]$$

the thickness of each slab is given by

$$h = \frac{FT}{2S} = \frac{F}{2N}, \qquad [3]$$

and the total length of rock broken is given by

$$D = hN = \frac{F}{2}, \qquad [4]$$

N = number of slabs
S = peak stress in incident pulse
T = tensile strength of the rock
F = fall length of incident stress pulse
h = thickness of each slab
D = total length of rock broken

During the reflection process the particle velocity at the free surface is twice the particle velocity in the incident stress pulse. Thus the velocity with which the broken fragments move forward is given by

$$v_f = 2\,\bar{v} \qquad [5]$$

where

v_f = velocity of broken fragment, and

$\bar{v}$ = average particle velocity contained in that portion of the incident pulse trapped in the broken fragment.

Results of these laboratory experiments cannot be applied directly to rock blasting where the explosive charge is placed in a drillhole. In laboratory tests the charge is unconfined and in contact with the rock in only one direction. In a drillhole additional confinement is offered by the rock surrounding the charge and by the stemming placed above it. This additional confinement may be enough to allow the explosive gases to do additional work on the rock during their expansion. Other writers have discussed possible effects of gas expansion on rock breakage.[13-16] However, very few experimental data are available to determine to what extent expansion of the gases is responsible for rock fragmentation.

The USBM has studied the physical processes involved in breaking rock with confined concentrated charges by using simple crater tests breaking to one free surface. Crater tests have been performed in four rock types: granite, sandstone, marlstone, and chalk. Table I gives some physical properties of these rocks. Fig. 2 shows plan and section drawings of two typical crater tests and illustrates some of the test variables measured. For these tests the charge was placed at the bottom of the drillhole and primed with an electric cap. The hole was stemmed to the collar with sand and the charge detonated. Size and shape of the crater were measured after it was cleared of broken rock.

As a given charge size was buried deeper in a drillhole, the crater depth usually was equal to or

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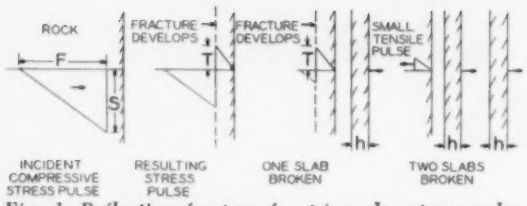

Fig. 1—Reflection fracture for triangular stress pulse. F = fall length of stress pulse, T = tensile-breaking stress, S = rock compressive stress, h = slab thickness.

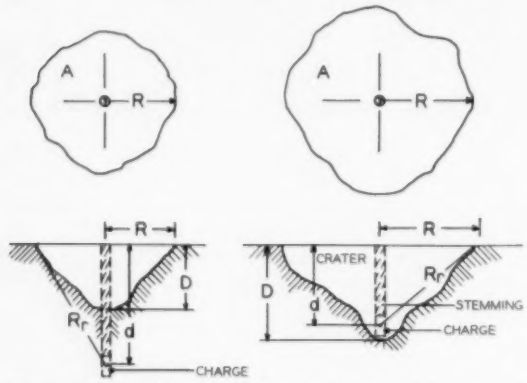

Fig. 2—Plan and section drawings for crater tests. A is the crater area; D, crater depth; R, crater radius; d, the charge depth; and Rr, the radius of rupture.

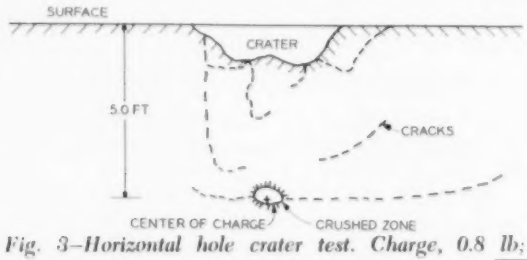

Fig. 3—Horizontal hole crater test. Charge, 0.8 lb; charge depth, 5.0 ft; scaled charge depth, 5.4 ft/$\sqrt[3]{\text{lb}}$.

slightly greater than the charge depth until a critical charge depth was reached; thereafter the crater depth became less than charge depth. A crater with a depth less than charge depth, as illustrated on the left in Fig. 2, indicates that energy has been transmitted from the charge point to the crater zone without causing damage to the intervening rock. Because the presence of the drillhole allows for the possibility that expanding gases may transmit this energy, long horizontal holes drilled from a vertical face were substituted for the drillhole in the crater zone. The length of hole was much greater than the depth of hole below the horizontal surface. A small charge of proper size to produce a crater depth less than the charge depth was placed at the back of the hole and the hole stemmed to the collar with sand. After detonation a vertical saw cut was made through the crater and shot point so that damage to the rock could be observed. Fig. 3 shows a crater produced by this type of test in chalk. Notice that there is a crater at the horizontal surface, a crushed zone around the charge point, and some additional cracking of the rock. As there is solid rock between the shot point and the crater zone, no gases were in the crater zone. Craters formed in this manner give convincing evidence that some form of wave motion transmits energy from the shot points to the free surface where damage to the rock occurs.

To study the wave motion generated when a charge is detonated in rock, the USBM developed a strain gage that could be cemented in drillholes in rock.[8] Fig. 4 shows the various parts of this gage and the completed assembly. The active element is an SR-4 strain gage, *B*, cemented into a brass cup, *C*, that previously had been cemented to a piece of drill core, *D*. The cup is covered by a lid, *A*, which provides a cable connection and a means of orienting the gage. A centering ring, *E*, is fastened to the core, and the whole assembly is cemented into a drillhole with a high-strength gypsum cement. Usually gages were placed in drillholes at various distances from the shot point, at the depth of the charge, and oriented to measure radial strain.

Outputs of the gages were recorded by high-speed oscilloscope drum cameras housed in the USBM mobile laboratory, which has 16 channels, each of which records on a 67-cm length of 35-mm film moving at 1000 or 2000 cm per sec. Photographic records obtained with this equipment are strain vs time plots. Enlarged drawings of typical strain records are shown in Fig. 5, which also illustrates and defines the measurements made on these records. Compressive strain is a deflection below the baseline and tensile strain a deflection above the baseline, and time increases left to right.

Typical strain records for granite and sandstone are presented in Fig. 6. Strain waves near the shot point are characterized by a single compressive pulse having a fast rise time and a slower decay time. As the strain pulse travels away from the

Table I. Physical Properties of Rock Types

Rock Type	Lithonia Granite	Green River Marlstone	Kanawha Sandstone	Niobrara Chalk
Formation Member	Lithonia Belt	Parachute Creek	Homewood	Smoky Hill-Fort Hays
Description	Gneissic	Kerogenaceous, dolomitic limestone (oil shale)	Coarse-grained	Chalky limestone
Apparent specific gravity	2.6	2.1	2.2	2.0
Compressive strength, lb per sq in.	30,000	10,000	10,000	2,000
Tensile strength, lb per sq in.	450	Not measured	70	Not measured
Tensile breaking strain, μin. per in.*	280	Not measured	500	Not measured
Modulus of rupture, lb per sq in.	2,000	400	400	300
Scleroscope hardness, units	85	45	30	10
Dynamic Young's Modulus, lb per sq in.	3.0×10^6	1.2×10^6	1.0×10^6	0.75×10^6
Modulus of rigidity, lb per sq in.	1.5×10^6	0.5×10^6	0.5×10^6	0.5×10^6
Longitudinal bar velocity, fps	9,000	6,000	5,000	5,000
Longitudinal field velocity, fps	18,500	13,000	5,000	7,500

* Microinch per inch = 10^{-6} in. per in.

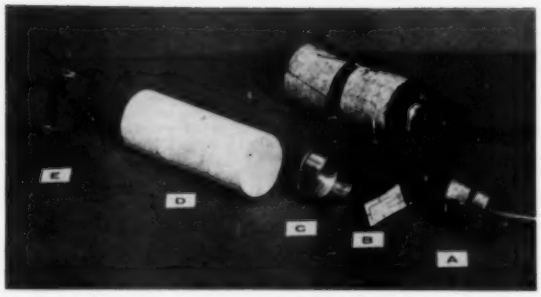

Fig. 4—The U. S. Bureau of Mines strain gage.

shot point its amplitude decays rapidly, and the pulse broadens and develops a small tensile phase. The rock type affects strongly the size and shape of the strain pulse, as is shown by comparison of strain records for granite and sandstone in Fig. 6. The type of explosive used mainly affected the amplitude of the strain pulse. Rise and fall times were not appreciably changed by the different explosives. Fig. 7 shows typical strain records in granite for three different explosives.

Strain-wave records were obtained at several distances for various charge sizes in the same rock types and with the same explosives employed in the crater tests. Measurements were made of peak strain, fall strain, rise time, and fall time. To eliminate the effect of charge size these data were scaled and plotted as functions of scaled travel distance. Distance is scaled to the charge size by dividing distance in feet by the cube root of the charge size in pounds. Time is scaled by dividing time in seconds by the cube root of the charge weight in pounds. Thus a scaled time multiplied by a propagation velocity in feet per second gives a scaled distance. Fig. 8 gives an example for granite.

A detailed study of reflected strain pulses shows that a conical crater should be produced above a concentrated charge buried below the surface. The depth of this crater should equal half the fall length of the strain pulse provided that half the fall length of the strain pulse is less than charge depth and provided that the fall strain is several times larger than the breaking strain of the rock.

If half the fall length of the strain pulse is greater than charge depth, reflected tensile breakage will occur only from the free surface back to the crushed zone. Reflected tensile breakage below the crushed zone is not possible in a simple crater test because of the geometry involved and the fact that the amount of tension developed during reflection decreases as the angle of incidence increases.

If the fall strain is only slightly greater than the tensile breaking strain of the rock, a crater is formed with a depth less than half the fall length of the strain pulse. Consider the case when the fall

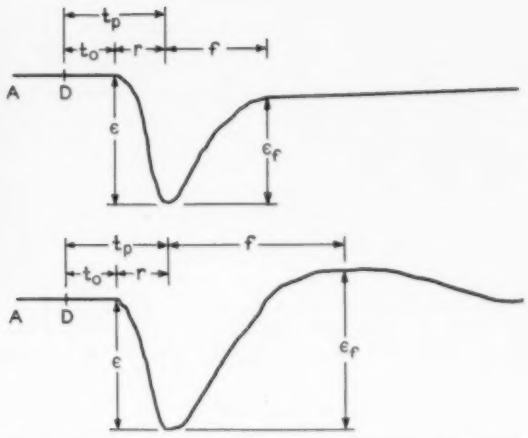

Fig. 5—Strain records showing the measurements made.
A = start of trace
D = time of detonation
ε = peak compressive strain
ϵ_f = fall strain
t_o = arrival time for start of pulse
r = rise time
f = fall time
t_p = arrival time for peak strain

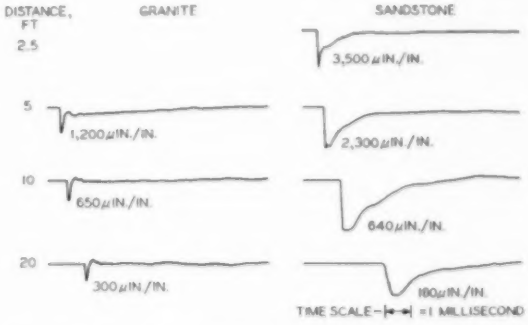

Fig. 6—Granite, sandstone strain records; 8-lb charge.

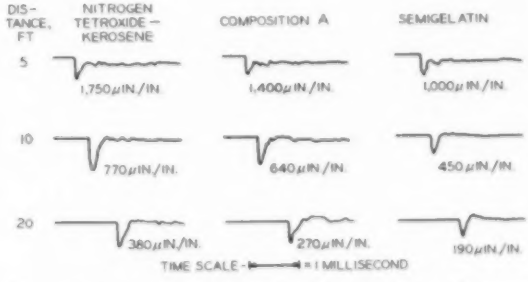

Fig. 7—Comparison of the strain records for different explosives. Rock type, granite. Charge weight, 8 lb.

Table II. Comparison of Dynamic and Static Tensile Breaking Strain of Rock

Rock Type	Maximum Scaled Crater Depth $D/\sqrt[3]{W}$ $Ft/\sqrt[3]{Lb}$	Scaled Charge Depth $d/\sqrt[3]{W}$ $Ft/\sqrt[3]{Lb}$	Scaled Travel Distance $L/\sqrt[3]{W}$ $Ft/\sqrt[3]{Lb}$	Fall Strain μ In. per In.	Dynamic Tensile Breaking Strain μ In. per In.	Static Tensile Breaking Strain μ In. per In.
Granite	0.8	1.9	2.7	720	360	280
Sandstone	1.6	1.5	3.1	1,100	550	500
Marlstone	2.2	2.3	4.5	620	310	—
Chalk	3.7	3.1	6.8	600	300	—

strain is exactly twice the breaking strain. In this instance just two slabs are produced, the bottom of the second slab occurring at a depth equal to half the fall length of the strain pulse. Next consider the case where the fall strain is slightly less than twice the breaking strain. Here only one slab is produced. The thickness of this slab is less than half the fall length.

The fall length of the strain pulse, F, is the fall time, f, multiplied by the propagation velocity, c, thus:

$$F = cf \qquad [6]$$

The distance traveled by the strain pulse during the reflection process of fracture, L, is the sum of the depth of the charge, d, and the depth of the crater, D, thus:

$$L = d + D. \qquad [7]$$

Therefore, the scaled equations for predicting crater depths for any charge size, W, from strain pulse data are:

$$\frac{D}{\sqrt[3]{W}} = \frac{1}{2}\,\frac{cf}{\sqrt[3]{W}} \quad \text{if} \quad \frac{cf}{2\sqrt[3]{W}} < \frac{d}{\sqrt[3]{W}}, \qquad [8]$$

$$\frac{D}{\sqrt[3]{W}} = \frac{d}{\sqrt[3]{W}} \quad \text{if} \quad \frac{cf}{2\sqrt[3]{W}} > \frac{d}{\sqrt[3]{W}}, \qquad [9]$$

$$\frac{d}{\sqrt[3]{W}} = \frac{L}{\sqrt[3]{W}} - \frac{D}{\sqrt[3]{W}}. \qquad [10]$$

The above equations are good only if the fall strain is greater than twice the breaking strain of the rock. Thus there is an upper limit on the value of $\frac{L}{\sqrt[3]{W}}$ that can be used to compute charge depth and crater depth. This upper limit can be specified for any rock type for which the dynamic breaking strain and the fall strain as a function of scaled travel distance are known.

Eqs. 8-10 have been used to calculate scaled crater depths for different scaled charge depths in the four rock types tested, using the scaled fall-time data given in Fig. 9. Results of these calculations are presented in Fig. 10 as a solid line showing the relation between scaled crater depth and scaled charge depth. The experimental crater data are shown as plotted points. For small scaled charge depths the experimental data and the calculated curves agree closely. For large scaled charge depths the experimental data lie below the calculated curves. This result is expected if the fall strain available in the strain pulse is less than twice the breaking strain of the rock. When this condition exists, one-slab craters are produced and the thickness of the slab is less than half the fall length of the strain pulse. Typical examples of these one-slab craters are shown in Fig. 11.

The dynamic breaking strain of rock can be estimated from crater and strain-pulse data. Maximum crater depth is produced by a strain pulse with a fall strain just twice the breaking strain of the rock. This strain pulse has traveled a scaled distance equal to the sum of the maximum scaled crater depth and the corresponding scaled charge depth. These experimental values can be read from Fig. 10. The fall strain corresponding to this scaled distance is determined from Fig. 12. One half the fall strain is the estimated dynamic tensile breaking strain of the rock. The results of these calculations,

Table III. Predicted and Measured Time of Breaking in Sandstone

Charge Depth, Ft	Horizontal Distance to Foil Strip, Ft	Arrival Time for Peak, M-Sec	Arrival Time for Peak Plus One Half Fall Time, M-Sec	Measured Break Time, M-Sec
0.4	1.0	0.14	0.96	0.39
	2.5	0.29	1.23	0.87
	5.0	0.63	1.75	1.05
0.9	1.0	0.17	1.02	0.27
	2.5	0.33	1.27	0.46
	5.0	0.66	1.80	1.05
1.8	1.0	0.25	1.15	0.38
	2.5	0.36	1.33	0.58
	5.0	0.68	1.83	1.30
2.5	1.0	0.32	1.31	0.57
	2.5	0.42	1.41	1.40
	5.0	0.74	1.94	2.60
2.9	1.0	0.36	1.33	0.62
	2.5	0.45	1.46	1.15
	5.0	0.77	1.93	2.50
3.9	1.0	0.48	1.50	1.33
	2.5	0.56	1.64	2.10
	5.0	0.84	2.14	4.02
4.7	1.0	0.61	1.72	1.23
	2.5	0.68	1.92	1.35
	5.0	0.95	2.37	3.50

Table IV. Velocities Determined from High-Speed Movies of Crater Tests in Sandstone, Charge Size 8 Lb.

Type of Explosive	Charge Depth, Ft	Stemming Velocity, Fps	Gas Velocity, Fps	Velocity of Rocks in Gas Stream, Fps	Rock Dome Velocity, Fps	Calculated Velocity of Rock Dome, Fps
Ammonia dynamite	0.44	2800	2800	360	—*	—**
Ammonia dynamite	0.44	3400	3400	240	—*	—**
Semigelatin	0.42	3000	3000	320	—*	—**
Semigelatin	0.42	4400	4400	180	—*	—**
Semigelatin	0.90	1800	1800	200	210	—**
Gelatin	1.80	1240	1800	180	120	—**
Semigelatin	2.4	900	1900	—†	80	74
Semigelatin	2.4	420	560	330	90	74
Gelatin	2.5	550	1600	105	70	72
Semigelatin	2.9	380	910	106	70	60
Gelatin	2.9	700	1050	210	50	60
Semigelatin	3.9	300	—‡	125	13	42
Gelatin	3.9	440	620	190	19	42
Semigelatin	4.7	82	—‡	51	9	32
Gelatin	4.9	105	—‡	—§	—§	30
Semigelatin	6.8	140	260	73	—§	16
Semigelatin	6.9	350	—‡	20	—§	16
Gelatin	7.0	27	—‡	—†	—§	15
Semigelatin	10.0	—§§	—‡	—†	—§	7

* No rock dome visible in picture.
** No strain data available for these distances.
† No pieces of rock observed in gas stream.
‡ No gas observed expanding out of hole.
§ No crater produced.
§§ Stemming did not come out of hole.

see Table II, show that the estimated dynamic tensile breaking strains are slightly greater than laboratory-determined static tensile breaking strains.

For some of the sandstone crater tests, strips of conducting foil were cemented to the rock surface in concentric circles around the charge hole in the expected crater area. These strips of foil were connected to circuits that generated a voltage pip when the foil strips were broken by cracking of the rock surface. Thus the time of rock cracking was determined by recording these voltage pips. These times are compared in Table III with the arrival times of the strain pulse at the break circuit. Specifically it is shown that breaking of the foil strips occurred after the arrival of the peak of the strain pulse and usually before half the fall time had elapsed. Four breaks occurred after half the fall time had elapsed. These late breaks occurred for the deeper charge depths and for the foil strips at the greater horizontal distances from the charge hole; they may result from a small time delay between the cracking of the rock and the breaking of the foil strips, because the rock is moving slowly at these larger distances.

High-speed movies of the explosions in sandstone were made with an Eastman high-speed camera capable of taking 3000 pictures a second. From these movies various phenomena during rock breakage were observed (Figs. 13-15).

For crater shots in sandstone having a scaled charge depth greater than 2.5 ft/$\sqrt[3]{\text{lb}}$, craters were seldom produced. High-speed movies of these tests show the sand stemming moving vertically upward with a constant velocity. Any loose rocks on the surface near the shot hole bounce upward before the top of the sand moves. Thus the seismic wave in the solid rock travels faster than it does in the sand stemming. However, the gases push the stemming out of the charge hole at a velocity higher than that of rocks bounced off the surface.

High-speed movies for crater shots in sandstone having a scaled charge depth less than 2.5 but greater than 0.5 ft/$\sqrt[3]{\text{lb}}$ show different phenomena. The sand stemming moves upward out of the charge hole followed by the explosion gases. There is an acceleration present in this motion. Cracks appear on the surface, and the broken rock moves upward, forming an almost perfect hemispherical dome underneath the gas cloud (Fig. 14). Little or no gas is observed issuing from the cracks in the rock dome. Out of the top there is a rush of gas and rock which appears as a conical funnel above the dome. Rock coming from the center is fragmented more than that forming the dome. Rock forming the dome has a constant velocity, with virtually no horizontal component, whereas the rock coming out of the top has a greater velocity, with both a horizontal and vertical component. Individual fragments can be observed as they separate because of the differences in their velocity. Rock near the center of the crater area has a higher vertical velocity than rock from the edges, and the surface fragments have higher velocity than those formed below the surface. The absence of a large horizontal component of velocity in the rock dome is convincing evidence that broken rock is not pushed out by expanding gas.

High-speed movies for crater tests having a scaled charge depth of 0.5 ft/$\sqrt[3]{\text{lb}}$ or less show no hemispherical dome of broken rock. Sand and gas expand out of the charge hole, followed by a rush

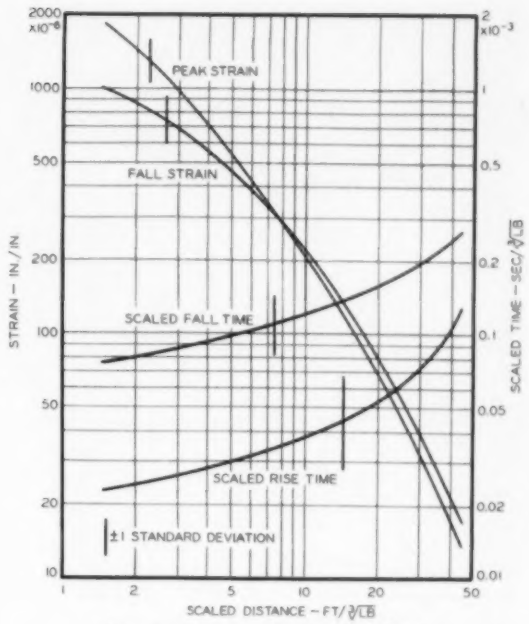

Fig. 8–Granite strain pulse data.

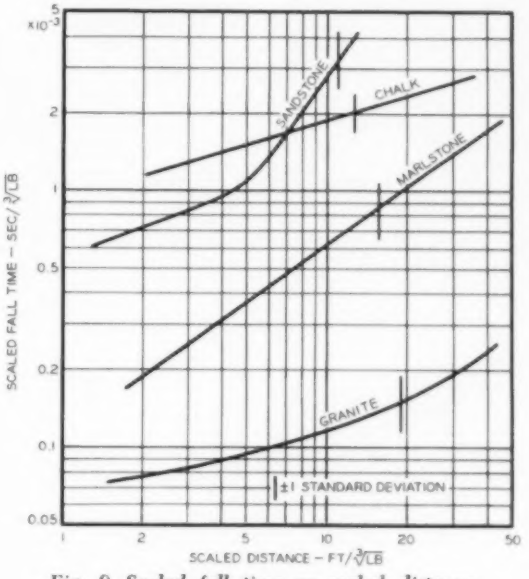

Fig. 9–Scaled fall time vs scaled distance.

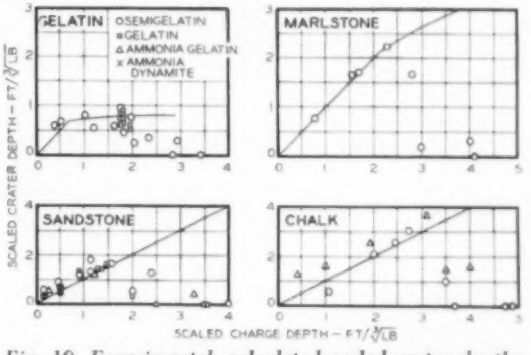

Fig. 10–Experimental, calculated scaled crater depths.

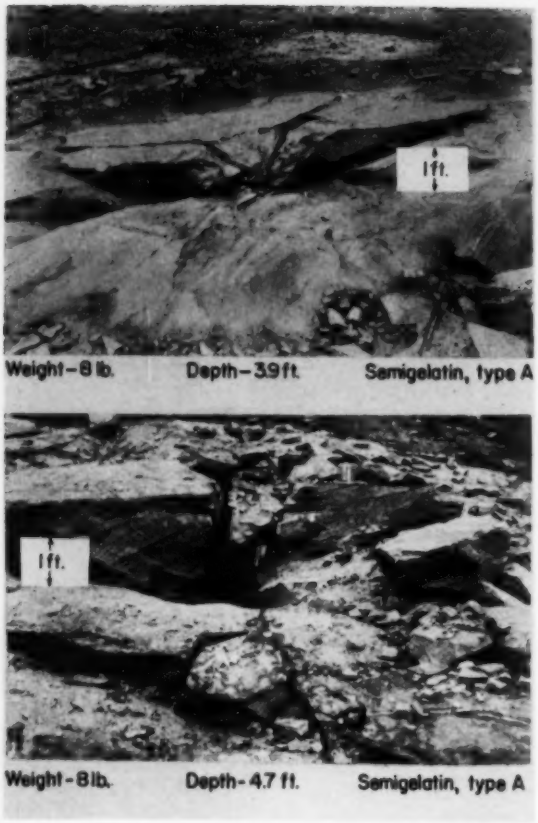

Fig. 11—Sandstone craters showing fragmentation.

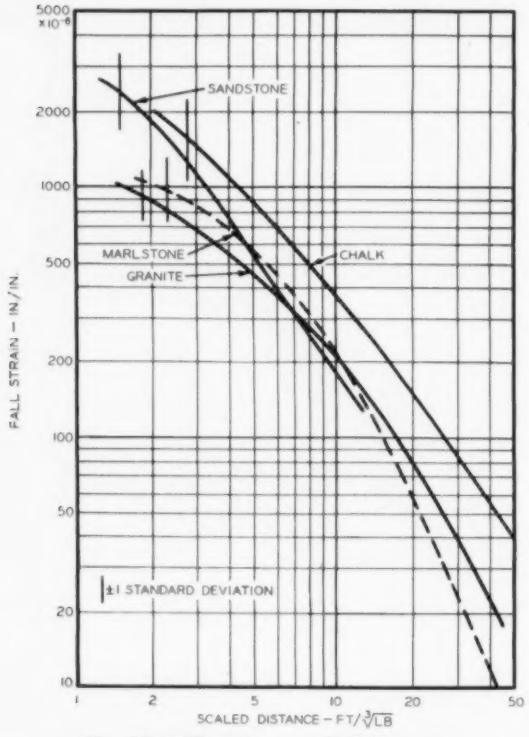

Fig. 12—Fall strain vs scaled distance.

of rock and gas out of the crater zone. This mass of broken rock and gas moves outward in all directions, forming an inverted cone above the crater. The rock is very finely fragmented and shows some acceleration.

The velocities of various motions observed in the high-speed movies were measured and are summarized in Table IV, where they may be compared with fly rock velocities calculated from peak strain data. These fly rock velocities were obtained by using Eq. 5 and the relation

$$v = c\epsilon \qquad [11]$$

where v = particle velocity, c = propagation velocity, and ϵ = peak strain.

Table IV shows that in general velocities of the various motions decrease as depth of charge increases. The expanding gases had the highest velocities; sand stemming velocities were lower than these except for the smallest charge depths, where there was so little sand on top of the charge that the gas and sand could not be distinguished from each other. Velocities of the rock dome are of the same order of magnitude as the calculated rock dome velocities, except for the larger charge depths. For large charge depths the first slabs broken are relatively thick; thus the velocity of these slabs is the average particle velocity trapped in the slab, whereas the calculated value was based upon peak values of particle velocity. Velocities of the rocks caught in the gas stream are greater than the rock dome velocities. This is to be expected, as the expanding gases have accelerated these rocks. Since most of the broken rock is contained in the dome that moves upward underneath the gas cloud, and since the velocity of this rock can be accounted for by the particle velocity associated with the strain pulse, it is evident that most of the rock fragmentation is a result of the strain pulse reflecting from the free surface.

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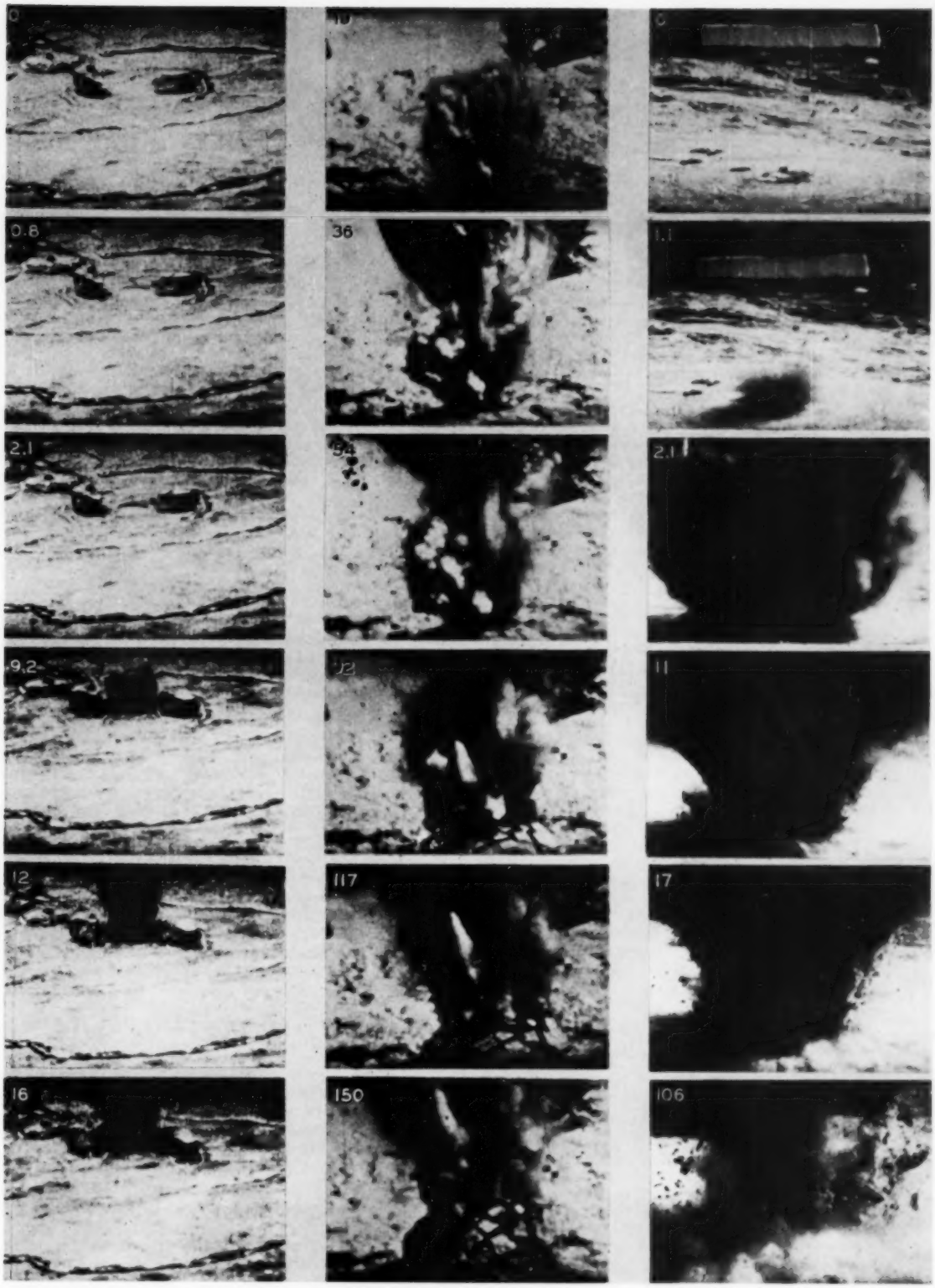


Figs. 13, 14, 15 (three columns, left to right)—High-speed pictures at different times after detonation of charge. Sandstone crater tests with scaled charge depths = 3.4 ft/$\sqrt[3]{\text{lb}}$, 1.45 ft/$\sqrt[3]{\text{lb}}$, and 0.25 ft/$\sqrt[3]{\text{lb}}$, respectively. Fig. 13—Charge, 8 lb semigelatin, type A; depth, 6.8 ft. Fig. 14—Charge, 8 lb gelatin, type A; depth, 2.9 ft. Fig. 15—Charge, 8 lb ammonia dynamite; depth, 0.5 ft. Millisecond numbers are given in the upper left of the photographs.

DISCUSSION

LINEAMENT TECTONICS AND SOME ORE DISTRICTS OF THE SOUTHWEST

by E. B. MAYO

(MINING ENGINEERING, page 1169, November 1958, AIME Trans., vol. 214)

David LeCount Evans (*Consulting Petroleum and Mining Geologist, Wichita, Kans.*)—Not only E. B. Mayo but also W. C. Lacy, who apparently urged the preparation of this analysis, is to be commended. Regional thinking of this type is needed to assure future success in the never-ending search for new mineralized and petroliferous districts.

As is usually the case, here is a regional study that will be read by the mining geologist alone. It is ironic that several of the trends established in this study have suggested themselves in northern mid-continent, detailed, and regional studies. These, where established, have offered new keys to petroleum exploration and have provided a possible basis for unraveling a number of broad generalities. The oil geologists, active in Colorado, Kansas, and Oklahoma, would find much food for thought in Mr. Mayo's projections.

To be more specific:

1) The parallelism between E. B. Mayo's Texas Lineament and the Amarillo Uplift, the Wichita Complex and the Arbuckle Complex of the Texas Panhandle and Southern Oklahoma is viewed with interest and appears especially significant when compared with the similar northwest trend of the Central Kansas Uplift, a major trend of production.

2) Considering the various northeast zones of Fig. 2, and with particular reference to Mayo's C-C, the Jemez Zone is on direct line with one of several northeast-southwest controls which the present writer has been using with some success in Kansas subsurface correlations. Considering zones of shearing, with no apparent vertical displacement, but suggesting strike-slip movement, because of the *staggered* effect on other features which cross such trends, Mayo's philosophy presents regional possibilities for lines of weakness, considered to this time of only local significance.

3) And, finally, in an area as distant from the Southwest as central Kansas, the north-south trends of the Fiarport-Ruggles anticline, the Voshel-Hollow Nikkel-Burrton structures, the Dayton to Stutgart trend, the north, slightly east trend of the Nemaha structural complex, and others all seem to approach the north-south alignments, *a* through *f*, of Mayo's Fig. 3.

Mayo's employment of structural intersections to pinpoint crustal weakness, to localize igneous activity and its accompanying mineralization is not, perhaps, a new concept, but it is a 1958 model, produced by tools improved from the ever-increasing accumulation of geological observations.

The use of intersecting trends in petroleum geology is not a new idea, since much production in earlier days was encountered via the straight line projections of established trends to centers of intersection.

A tragedy in this age of specialization is that *iron curtains* have been raised between groups, all seeking raw materials, all acolytes at the altar of structural geology, but all smugly content in and protected by the ivory towers of petroleum geology, engineering geology, mining geology, and geophysics.

Mayo presents basic ideas which can stimulate mid-continent structural thinking and, in the case of central Kansas, he provides a key to replace the broad and overworked simple monoclinal, sinkhole-dotted, Karst topography credo, which is not finding its share of new oil in a state where the declining discovery ratio is disconcerting.

The American Association of Petroleum Geologists would do well to add E. B. Mayo to its list of Distinguished Lecturers.

Evans B. Mayo (*author's reply*)—In reply to David LeCount Evans' comments, it is pleasing to learn that some of the elements discussed in my paper may interest petroleum geologists as well as mining geologists. This should not be surprising, however, because the lineaments make up the framework of the continent, and the oil-bearing sediments must reflect to varying degrees adjustments of basement blocks along their boundaries. A further possibility that petroleum geologists must have considered is that the slow escape of heat from buried lineaments and their intersections has aided the separation of oil from the sediments and started the migration into traps.

Regarding the specific points listed by Evans, the following are suggested:

1) The branch of Texas Lineament marked 1′ (Fig. 3) is thought to extend eastward through the Capitan Mts., New Mexico, through the long Tertiary dikes east of Roswell, and beyond via the Matador and Electra ranges of the Red River Uplift, Texas. Its further continuation might be the eastern flank of the Ouachita Fold Belt. The Amarillo-Wichita-Arbuckle zone of uplifts appears to continue east-southeastward the Spanish Peaks belt (3-5, Fig. 3). The northwest-trending Central Kansas Uplift would not belong to the above set, except insofar as the Central Kansas Uplift is traversed by west-northwest folds, possible continuations of the Uinta belt (5-5, Fig. 3).

2) The possible continuations into Kansas of the Jemez zone are new to me and are most welcome suggestions.

3) Most of the nearly north-south Kansan structures mentioned by Evans are unfamiliar to me, but the Nemaha Uplift itself appears to be part of a very pronounced structure traceable from the Cerralvo Fault Zone, south of the Rio Grande, through the Bend Arch, Texas, and the Nemaha Uplift, into the Pre-Cambrian of Minnesota (?). This nearly meridional zone is crossed and broken by the Rio Grande Embayment and by the Red River-Wichita Syntaxis. Petroleum geologists realize the economic importance of these features.

Perhaps it is inevitable that some papers of general interest be *buried* in the journals of specialized groups. Moreover, papers dealing with regional, or lineament, tectonics and its applications to exploration for economic mineral deposits are as yet few in the American literature. The opportunity to advance this field is open to all those who are not ultra-conservative and who have a lively curiosity, plenty of patience, and not too many business restrictions.

In conclusion, much appreciation is extended to D. L. Evans for his comments.

EFFECT OF PULP DEPTH AND INITIAL PULP DENSITY IN BATCH THICKENING

by A. M. GAUDIN, M. C. FUERSTENAU, and S. R. MITCHELL

The two principal attributes of a thickener pulp are its settling rate and the ultimate pulp density of the thickened mud. Testing for evaluation of thickening attributes of a pulp has usually been done batch-wise by placing the pulp in a one-liter glass graduated cylinder and noting the position of the boundary between clear liquor and mud as a function of time. Refinements in testing have included repulping a thickened mud to various dilutions and evaluating the settling rate on these various repulped muds. This is considered to make possible an estimate of the settling rate as a function of pulp density and therefore to pinpoint the slowest settling pulp which ought to be critical from the standpoint of thickener plant design. Finally, tests are sometimes made with model-size continuous thickeners of arbitrary size.

In batch tests it is generally accepted that the behavior of a pulp is described by a curve such as the one shown in Fig. 1, in which the position of the boundary between clear liquor and mud (the mudline) is plotted against time. It has also been assumed that the initial settling rate (the slope of the line segment *AB*) is descriptive of the pulp and independent of the size and shape of the container. Where the settling rate is slower and clearly a function of time (portion *CD* of the settling curve), it has been assumed that the data are not of much use because of the intrusion of compacting phenomena. The next important datum is the height, *PE*, which is a measure of the so-called *ultimate pulp density*. This quantity is assumed to be characteristic of the pulp and independent of the container.

When actual data are recorded, results are rarely exactly according to this theory and numerous deviations may be noted. For example, some pulps seem to require an appreciable delay before beginning to settle, as in line *AF*. This is spoken of as representing the need for an *induction time* for flocculation.

It has seemed desirable to explore thickener data with a more sensitive charting tool than is afforded by the coordinates of Fig. 1. Instead of relating the position of the mudline to time, it has seemed desirable to relate the rate of descent of the mudline to time. This, in effect, amounts to charting the slope of the line in Fig. 1, or the derivative of its ordinates, against the same abscissas. Fig. 2 shows the new chart for the curve *ABCDE* of Fig. 1.

When this new tool was applied to data obtained, for example, with sized clay pulps, astonishing differences appeared. Apparently the traditional tool conceals differences instead of revealing them, whereas the new method emphasizes them. It seems, also, that both charting methods have their uses.

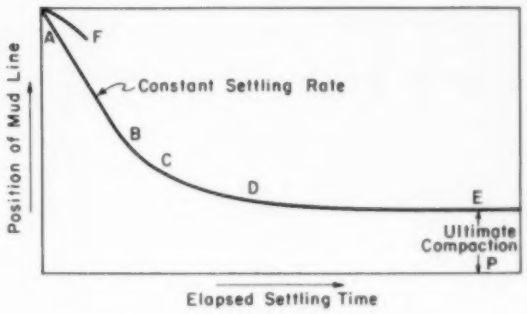


Fig. 1—Normal settling curve.

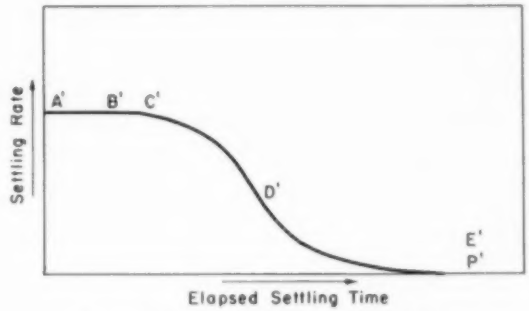


Fig. 2—Differential curve for data of Fig. 1.

In this article attention is focused on the effects of pulp density and container height as they affect the settling behavior of flocculated suspensions of a sized kaolin. The thesis by M. C. Fuerstenau[1] gives more details than this summary, as well as some information about the effect of other variables.

Sized fractions of kaolin were used, supplied through the courtesy of S. C. Lyons of the Georgia Kaolin Co. Large batches were made by agitation in a flotation machine and in a glass jar equipped with a mixer. The settling vessels were 2, 4, and 6-in. diam glass cylinders of various heights.

Pulp Dilution: The effects of pulp dilution on sedimentation behavior are shown in Figs. 3, 4, and 5. Fig. 3 shows data on pulps ranging from 2.44 to 16.7 pct solids initial pulp density, flocculated with Separan and charted in the traditional manner. At least two of the lines appear nearly straight in their early sections, but neither of the others does. Each of the curves in this figure includes a region labeled

A. M. GAUDIN, Member AIME, is Richards Professor of Mineral Engineering; M. C. FUERSTENAU, Student Member AIME, is Research Assistant; and S. R. MITCHELL is Senior Technician, Massachusetts Institute of Technology, Cambridge, Mass. TP 4806B. Manuscript, Jan. 2, 1959. AIME Trans., Vol. 214, 1959.

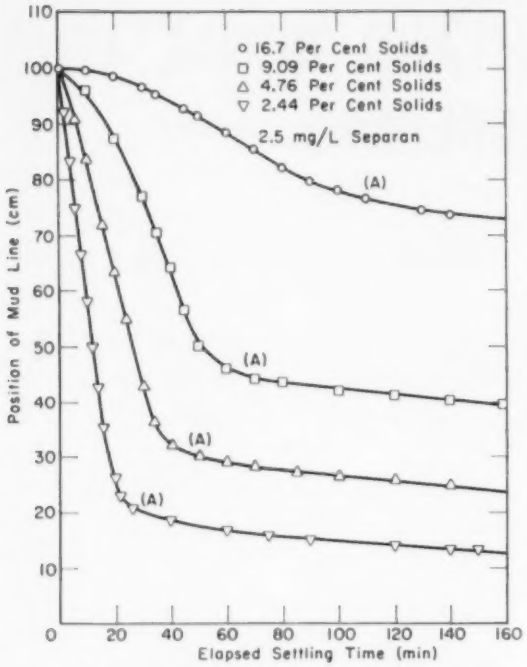


Fig. 3—Relation between position of mudline and elapsed time at various pulp dilutions (kaolin 2 to 20μ).

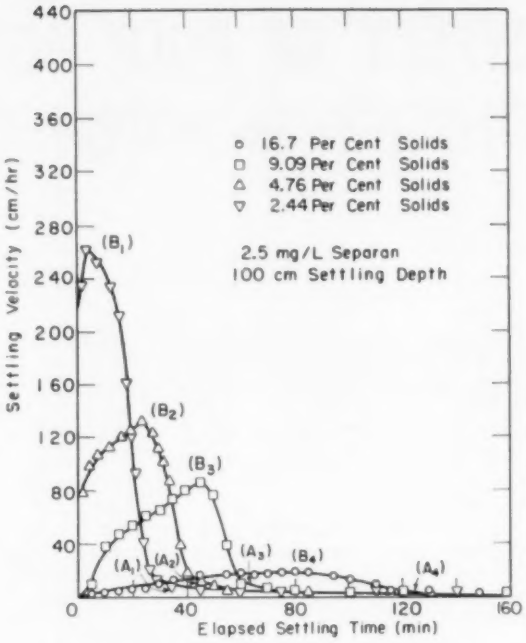


Fig. 4—Relation between settling velocity and elapsed settling time, various pulp dilutions (kaolin 2 to 20μ).

(*A*) in which the settling changes radically, becoming relatively slow. Fig. 4 is a plot of the same data, charted in terms of settling velocity vs time. It is clear that no horizontal section is shown in any of the curves and, therefore, that the conclusion of linearity for the early part of two of the curves in Fig. 3 is in error. The curves in Fig. 4 were drawn from the numerical data from which Fig. 3 was drawn, each of the points for the curves of Fig. 4 having as ordinate the difference of two numbers representing the mudline position at succeeding time intervals.

Fig. 5 shows data on similar pulps flocculated with lime instead of Separan, the data being charted as in Fig. 4. The purpose of Fig. 5 is to show that the behavior represented by Fig. 4 is not ascribable to the new flocculant, since similar results are obtained with the traditional lime.

As the concentration of solids in the feed pulp is decreased, maximal settling velocity increases and is attained sooner (points *B*, for example, in Figs. 4 and 5). At great feed-pulp dilution, maximal settling velocity is obtained at the very beginning of settling, but with thicker pulps more or less time must elapse before maximal mudline settling velocity is attained.

The time required for condition *A* to appear (Figs. 3 and 4) is shortened as the pulp is made thinner. The appearance of condition *A* is marked by formation of *volcanoes* at the mudline from which small flocs erupt, as noted by Coe and Clevenger.[3]

Settling Depth: Settling depth has heretofore not been regarded as a factor in the behavior of batch-settling thickener pulps. The writers found it to be of major importance. Tall settling columns (100 and 200 cm in height) as well as settling columns of more usual height (25 and 50 cm) were used in this study.

When dilute pulps are under consideration, as shown in Fig. 6, maximal settling velocity is substantially independent of settling depth (points *B*). Also, maximal settling velocity is attained early in the sedimentation period and occurs at almost the same time for all settling depths. The shorter the settling depth, the more rapid the rate at which settling velocity decreases after the maximum is attained. In fact, if the settling velocity is plotted against the ratio of settling time to initial depth, the data from all the tests fall on about the same line (Fig. 8A). Thus the decay in settling velocity with *relative time* seems the same in all cases. No doubt the decrease in settling velocity as settling proceeds is due to the increased pulp density, and this increase occurs more slowly when tall vessels are used.

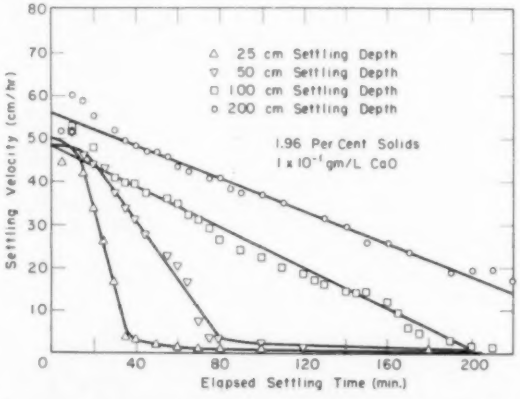

△ 25 cm Settling Depth
▽ 50 cm Settling Depth
□ 100 cm Settling Depth
o 200 cm Settling Depth
1.96 Per Cent Solids
1 x 10⁻⁴ gm/L CaO
Settling Velocity (cm/hr)
Elapsed Settling Time (min.)

Fig. 6—Showing the relationship between the settling velocity and the elapsed settling time for various settling depths at high pulp dilution (kaolin 0 to 2μ).

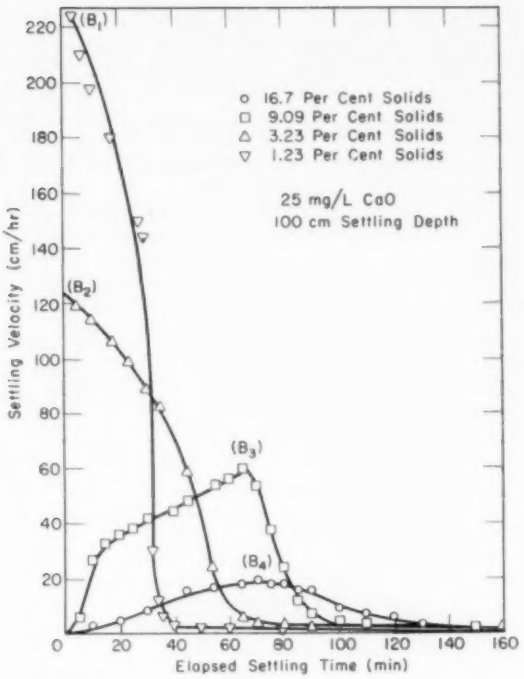


Fig. 5—Relation between settling velocity and elapsed settling time, various pulp dilutions (kaolin 2 to 2μ).

When thicker pulps are settling, e.g., 10 pct kaolin by weight, a profound difference in maximal settling velocity exists between pulps settling in shorter vessels and those settling in taller vessels, as shown in Fig. 7. Also, the time to attain condition *A* is greater for greater settling depth. If a plot is made of settling velocity vs relative time, the data for vessels of various depths do not fall on the same line, wherein they differ from the data obtained with dilute pulps. This is brought out clearly by Fig. 8, which is composed of four parts that show data for the settling of pulps of the same kaolin made up to various dilutions and placed in vessels of various heights. The vessels used were 25, 50, 100, and 200 cm in height and the pulp dilutions were 50 parts of water to one of solids, 30:1, 15:1,

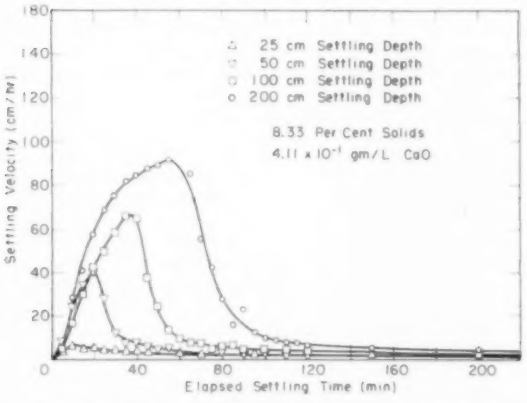
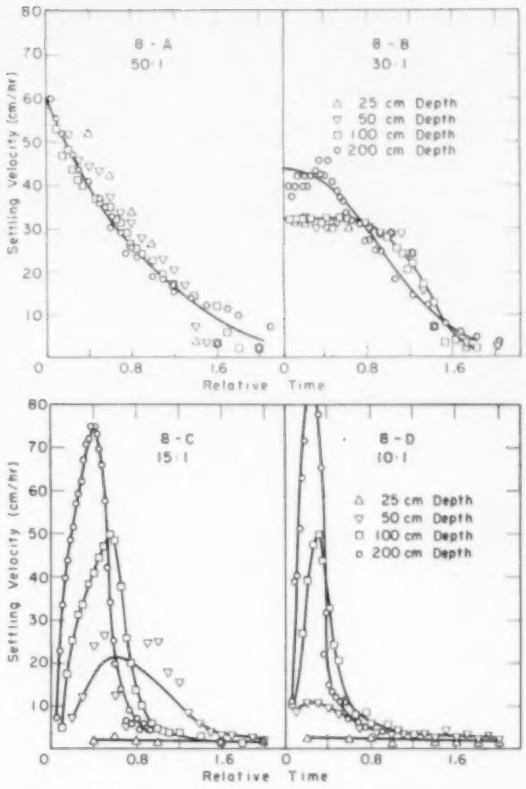

△ 25 cm Settling Depth
▽ 50 cm Settling Depth
□ 100 cm Settling Depth
o 200 cm Settling Depth
8.33 Per Cent Solids
4.11 x 10⁻¹ gm/L CaO
Settling Velocity (cm/hr)
Elapsed Settling Time (min)

Fig. 7—Showing the relationship between the settling velocity and the elapsed settling time for various settling depths at lower pulp dilution (kaolin 0 to 2μ).



Figs. 8A through 8D—The relationship between the settling velocity and the relative time for various settling depths at various pulp dilutions (kaolin 0 to 2μ).

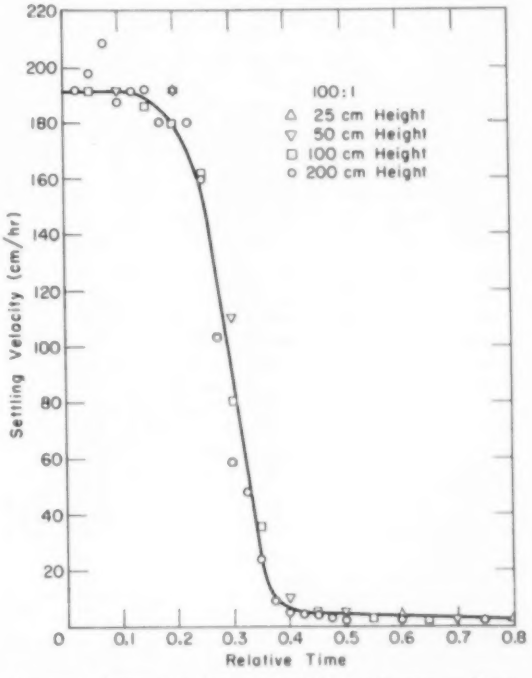


Fig. 9—Relationship between settling velocity and relative time at very high pulp dilution (kaolin 0 to 2μ).

and 10:1. In all cases the pulps were flocculated with lime. The amounts were different if rated on the liquid but the same if rated on the solids. Additional experiments made with other pulp dilutions are omitted for the sake of brevity; these experiments were made at 100:1, 40:1, 20:1, 12:1, and 8:1. They tell the same story.

The experiments made at 100:1 provide the one instance approximately constant settling rate was attained at the beginning of settling. Otherwise, they are the only experiments that accord with the accepted theory of settlement of flocculated suspensions. For the record, a chart of settling velocity vs relative time is included in Fig. 9. (Note that the scale of ordinates is much condensed from those in Fig. 8, while the scale of abscissas is expanded.)

Discussion: It has generally been thought that in a settling column of pulp that is initially of uniform pulp density throughout its height, two zones form shortly after the start of the settling process. The lower zone was thought to consist of compacting sediment and the upper zone of relatively fast-settling flocs. It was believed that this upper zone did not change in pulp density from top to bottom, or in time, but merely in the extent of its vertical dimension.

Since the settling of the mudline is so strongly dependent on the height of pulp initially placed in the batch thickener, it may well be suspected that the above ideas—while correct in respect to the existence of two zones and the time-and-position variability in pulp density of the lower zone—are incorrect in respect to the homogeneity of the upper zone.

This reasoning has led to construction of a device for measuring pulp density continuously as a function of time and position and without disturbance. This device, the Transviewer, has already been described, and work with it is actively in progress.[8] The phenomena described here explain why it is believed the Transviewer will serve a useful purpose in the development of thickening theory.

The authors are grateful for the financial support provided by Crucible Steel Co.; Duval Sulfur & Potash Co.; Engineering Foundation, Georgia Kaolin Co.; and the U. S. Atomic Energy Commission.

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[8] A. M. Gaudin and M. C. Fuerstenau: The Transviewer—X-Rays to Measure Suspended Solids Concentration. *Engineering and Mining Journal*, 1958, vol. 159, no. 9, pp. 110-112.

Discussion of this article sent (2 copies) to AIME before July 31, 1959, will be published in MINING ENGINEERING.

DISCUSSION

SCALE-UP RELATIONSHIPS IN SPODUMENE FLOTATION

by W. E. HORST

(*MINING ENGINEERING*, page 1182, November 1958, *AIME Trans.*, vol. 214)

John Dasher (*Central Research Laboratory, Crucible Steel Co. of America, Pittsburgh, Pa.*)—Getting spodumene to float quickly and cleanly can be a problem. The author has presented an excellent account of a valid and useful approach to the scale-up of such problem floats. This indicated advantages for doubling retention time, i.e., buying another set of flotation cells.

The author states that 21 pct of the spodumene floated in 2 min in the laboratory cell, that the grade of the rougher was about 75 pct spodumene, and that the final tailing contained 4 to 12 pct spodumene in different sizes with the present cells and 1 to 9 pct spodumene with twice as many cells.

About 20 years ago, this writer obtained in the laboratory the flotation of over 90 pct of this spodumene in a King's Mountain sample in 1 min at a grade of 90 pct spodumene in the rougher and a final tailing that contained only 1 pct spodumene. The methods of Norman, Ralston,[6] and Gieseke[7] were used, which teach that spodumene floats quickly and cleanly if its surfaces have been properly conditioned chemically and/or mechanically prior to flotation.

Although feed preparation is not discussed, the results reported indicate that it is inadequate. This writer suggests that improvements in this area might be more effective than doubling the number of cells.

W. E. Horst (*author's reply*)—Dasher's comments are appreciated by the author and require some clarification. He suggests that improved spodumene flotation performance may be obtained by feed preparation techniques rather than increased retention time in flotation. Certainly flotation performance is dependent on feed preparation and this is an important feature in the flotation process. It is true that certain types of spodumene ores, particularly weathered ores, require more complicated feed preparation processing than clean ores to achieve the desired flotation results. It was not implied that current feed preparation techniques are the same as experienced during the scale-up investigations.

Although discussion of feed preparation was omitted from the article on scale-up relationships, the important feature was that pre-treatment processing was the same for each level of operation investigated—laboratory, pilot plant, and plant scale. Under these similar conditions large differences existed in recovery for comparable time intervals in each scale of operation. It is highly probable that feed preparation techniques could be modified and thereby increase the flotation rate for each scale or all scales of operation discussed. However, modifications would have to be justified on an economic basis.

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[6] J. E. Norman and O. C. Ralston: Conditioning Surfaces for Froth Flotation. *AIME TP 1074B*, 1939, p. 85.
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DRILL CORE SCANNER PROVED IN FIELD

Solid phosphor core scanner offers rapid and reliable method of checking radioactivity as drill core is moved automatically through high-sensitivity chamber. Continuous graph of radiation intensity is plotted.

by W. W. VAUGHN, R. H. BARNETT, and E. E. WILSON

Soon after the search for uranium ores on the Colorado Plateau began in earnest, thousands of feet of drill core ranging from 1⅛ to 2⅛ in. diam became available for study. Although significant advances had been made in the technique of quantitative gamma-ray borehole logging, instrumentation was in the development stage, and complete reliance could not be placed on gamma-ray logs alone to interpret quantitatively the meaning of radioactivity in a drillhole. A method that would be faster than chemical analysis and still give reproducible and reliable results for various drill core sizes was desirable to provide additional information on the enormous footage of drill core being accumulated.

A solid phosphor scintillation drill core scanner was designed and constructed. Basically the instrument was developed to measure radiation from a drill core which would not be clearly recorded by a gamma-ray logger using a Geiger tube as the sensitive element. Such data would be beneficial in constructing isorad maps to delineate ore-bearing zones. A calibration in the range 0.01 to 0.1 pct eU_3O_8 was provided; above 0.1 pct eU_3O_8 gamma-ray logs were available and were being used to calculate grade and tonnage of ore reserves. The core scanner, however, has been used to estimate equivalent uranium content of ore-grade materials containing as much as 2.2 pct eU_3O_8 with an accuracy of ± 10 pct, the sample being in the form of a BX drill core. Actually, an apparent calibration of eU_3O_8 vs counts per unit time is a straight line with a slope that is a function of the sensitive element and the geometry of the counting assembly. A true calibration that will show the expected departure from a straight line is due principally to the random nature of the pulse from a radiation source and the nonlinearity of the electron circuitry.

Design and Construction: Three methods of detecting radioactivity were considered and applied in developing the core scanner now in use: 1) the Geiger tube, 2) liquid scintillation phosphors, and 3) solid scintillation phosphors. The desired sensitivity and long-term drift characteristics needed for this operation could be attained only by using solid scintillation phosphors. All three methods are discussed.

Before scintillation counters were common, nine beta-gamma sensitive Geiger tubes ⅞ in. diam by 12 in. long were used, arranged to surround the drill core with tube axes parallel to the axis of the core. This arrangement of Geiger tubes was enclosed in a lead shield 1 in. thick, and provision was made to slide a 6-ft length of drill core manually into the counting chamber, one foot at a time. A count for each segment was taken with a scaler while the core remained stationary. The equivalent uranium content of the different sections of drill core could then be estimated with the aid of a calibration curve of counts per unit time vs percent equivalent uranium (eU). In rare cases the effects of the radioactivity concentrated in small areas within the core introduced errors in the readings made with the Geiger tube arrangement owing to the geometry of the measurement. The variability of counting rate due to a localized concentration of radioactivity in a spot in the wall of a drill core is illustrated in Fig. 1. This effect and the inherent low efficiency of the Geiger tube were considered major disadvantages of this counting arrangement.

When liquid scintillation phosphors became available the core scanner in Fig. 2 was constructed to make a more accurate measurement of the equivalent uranium content of a sample. This instrument contains about 4 liters of liquid phosphor in a stainless steel coaxial cylinder 1 ft long, with inner and outer walls 0.060 in. and 0.125 in. thick, respectively. Four end-window type photomultiplier tube with cathodes of 2 in. diam, immersed in the solution at right angles to the axis of the core, were used to observe light flashes in the phosphor. The liquid phosphor offered equal sensitivity to radiation originating at any point in the enclosure and represented geometrically the optimum in design. However, providing a semi-permanent leak-proof seal between the glass envelope of the phototube and the metal walls of the container proved to be a serious problem in constructing the equipment. The most effective seals were especially machined O-rings from sections of large tygon tubing. The tygon took a permanent set owing to cold flow characteristics and in most cases sealed completely. The light absorption characteristics of the liquid phosphor changed gradually with time, and after one month the counting rate had decreased to half the original value. The most sensitive liquid phosphor tested proved to be a solution containing 4 g of 2.5-diphenyloxazole and 0.01 g of 2-(1-naphthyl)-5-phenyloxazole per liter of toluene. With fresh solution in the chamber and with all photomultiplier tubes operating in parallel, the counting rate contributed by any one of the four photomultiplier tubes was about 85 pct of the counting rate from a single tube operated individually. From these observations it was concluded that owing to coincident loss and light attenuation within the liquid phosphor, the apparent sensitivity could not have been materially increased by additional phototubes. However, this approach to core

W. W. VAUGHN, Chief, R. H. BARNETT, and E. E. WILSON are with the Electronics Laboratory, Geophysics Branch, U. S. Geological Survey, Denver. TP 4802I. Manuscript, Sept. 29, 1958. AIME Trans., Vol. 214, 1959.

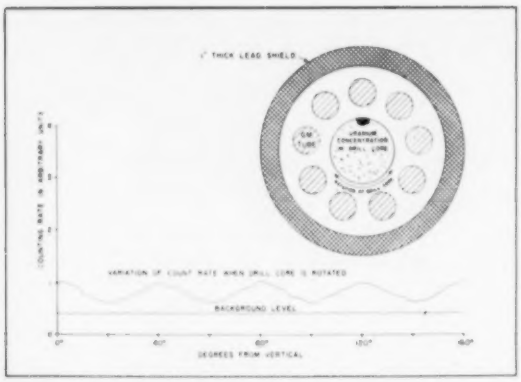

Fig. 1—Idealized counting geometry, GM tube scanner.

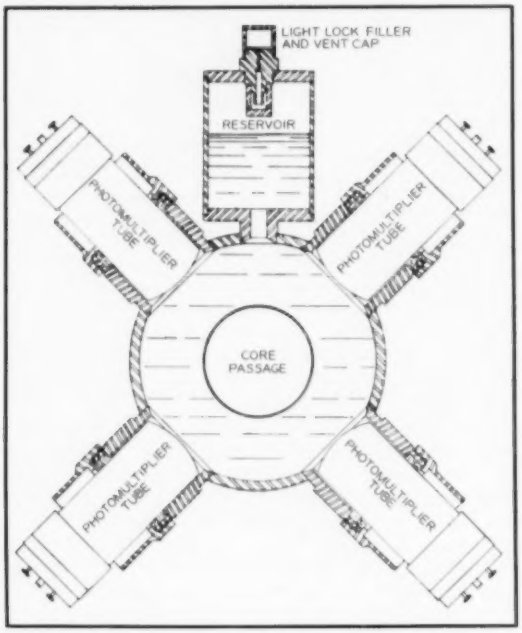

Fig. 2—Liquid scintillator core scanner. Section through reservoir and photomultiplier tube holders.

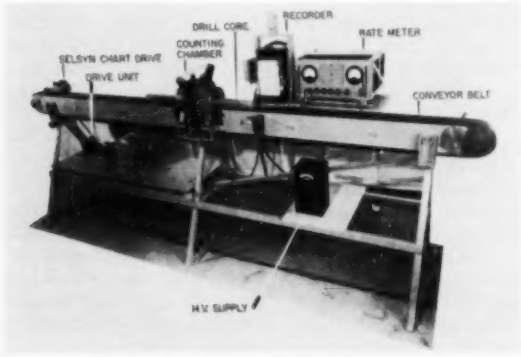

Fig. 3—Solid phosphor detector scanner.

scanning was abandoned because of long-term drift characteristics which were caused by gradual discoloration of the solution and the subsequent increased attenuation to light transmission in the range of 4000 to 6000Å.

Because of the greater sensitivity per unit volume and the long-term stability of light output from sodium iodide crystals immersed in the higher-viscosity silicone fluids, a core scanner with this type of phosphor was developed (Fig. 3). A thickness of about 2 in. of lead is used to shield the sensitive area except for the openings of the photomultiplier tubes and the passageway for the drill core. Four sodium iodide crystals 2 in. diam by 2 in. long, mounted individually in spun aluminum cups of 0.032-in. wall thickness, are spaced radially at right angles around the drill core. Approximately 3 π geometry is obtained in the counting chamber with this arrangement. Each crystal is immersed in silicone compound of 200,000 centistokes viscosity and coupled optically with the same silicone compound to the 2-in. diam cathode of an end-window type of photomultiplier tube.

The crystals and phototubes were selected individually from stock for uniformity of spectral response, resolution, and low microphonics, and the amplification factors were matched when possible. The resistor divider system for the dynodes of the phototubes used 5-megohm, ¼-watt resistors between all dynodes except 5, 6, and 7. A 5-megohm potentiometer and two 2½-megohm, ¼-watt fixed resistors connected between dynodes 5 and 7 of each phototube (with the arm of the potentiometer connected to dynode 6) control the amplification of the photomultiplier tubes (Fig. 4). The divider system, including the 5-megohm potentiometer, is molded in a silicone rubber compound called 3M Dielectric sealer EC-1120-PC. Two leads for the high voltage connection were brought out external to each mold and the four tubes were connected in parallel. Since the amplification factor of the phototube varies roughly as the fourth power of the dynode voltage, it is desirable to have the voltage across the dynode resistance change as little as possible with counting rate. The secondary emission electrons flowing internally from dynode to dynode within the phototube fluctuate wih the radiation impinging on the sodium iodide crystal. The end result of this fluctuation of phototube current is the effect of varying resistance in parallel with a fixed resistance, the external dynode resistor divider system. The current, particularly between dynodes

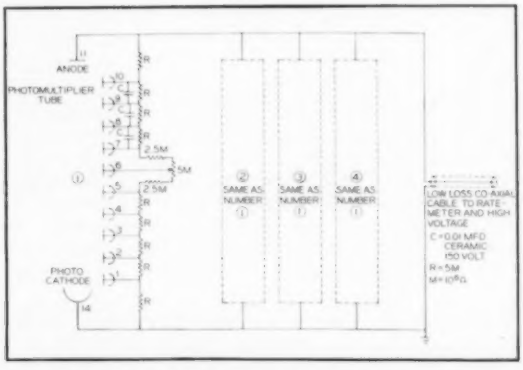

Fig. 4—Solid phosphor detector assembly.

8 through 10, is considerable at high counting rates. The voltage decreases due to the decrease in resistance resulting from the shunting effect of the high-density current may be as much as 10 v on these dynodes. Since the overall voltage across the divider system remains constant, other dynode potentials will rise as a result of this redistribution of current. This fluctuation of voltage may be minimized in two ways: a glow discharge type of voltage regulator tube may be used between dynodes in the divider system, or the value of the fixed resistors may be decreased (providing the high voltage supply will stand the additional current drain).

The latter choice was made, and the high voltage supply (Fig. 5) separate from the rate meter was constructed to supply the load presented by the four phototubes in parallel. The high voltage supply is a series-parallel type with a regulation of 0.001 pct change in line voltage. A 7A4 vacuum tube in series with a bleeder resistor controls the high voltage. A 6AG5 vacuum tube in parallel with the bleeder resistor compares a sample of the output voltage with a reference voltage obtained from the cascaded voltage-regulator tubes (VR 150 and VR 105) and amplifies the difference in voltage. This amplified error voltage appears at the grid of the series regulator tube, effecting control by varying the conductance and voltage drop across this tube. When the high voltage output decreases, the grid of the 6AG5 tube becomes less positive, the plate and the grid of the 7A4 tube less negative. The increased conductance in the 7A4 tube causes less voltage drop. The four phototubes have a common load resistor where a voltage pulse is developed and fed to the rate meter circuit. A commercially available rate meter, EK Cole Model 522, and a 1-ma graphic recorder are used to count and record results.

Physical Assembly: The frame for the core scanner, constructed of 1½-in. angle iron, is approximately 12 ft long and stands 3 ft high. The 4-in. wide conveyor belt, which can accommodate 6-ft lengths of core, is driven through a variable-speed pulley arrangement by a reversible motor. Manual adjustments to set the tension and angle of belt travel are provided at each end. Wooden guide rails, which can be changed for drill cores of various diameters, tend to cup the ¼-in. thick conveyor belt before it enters the counting chamber. The chart drive in the recorder, which has five interchangeable gear ratios, is driven by a selsyn and gear box from the pulley system moving the belt. The depth to which the phototubes may be inserted into the lead-

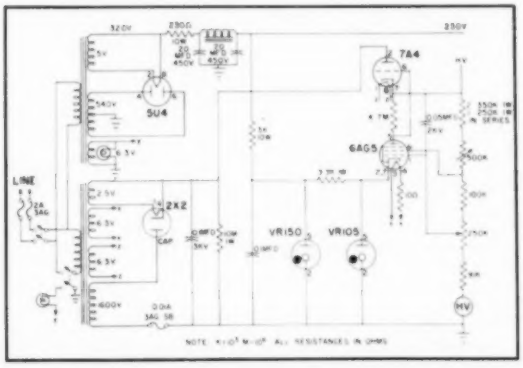

Fig. 5—High voltage supply for solid phosphor scanner.

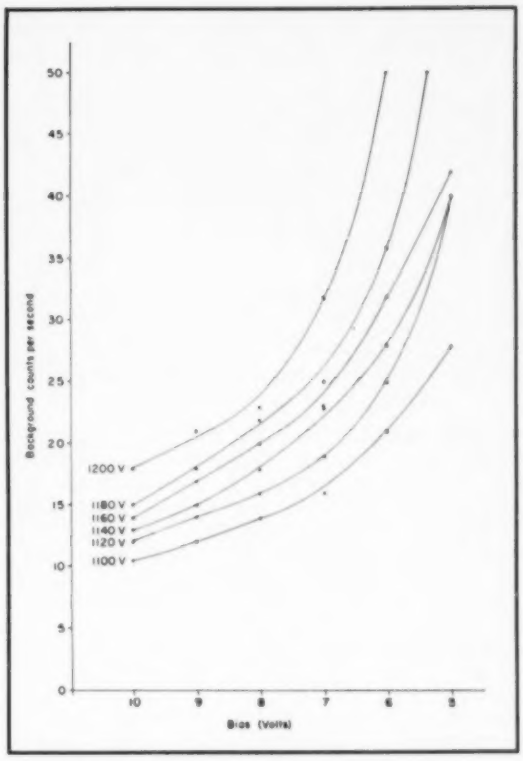

Fig. 6—Graph showing the fluctuations in background with bias level at different high voltage settings.

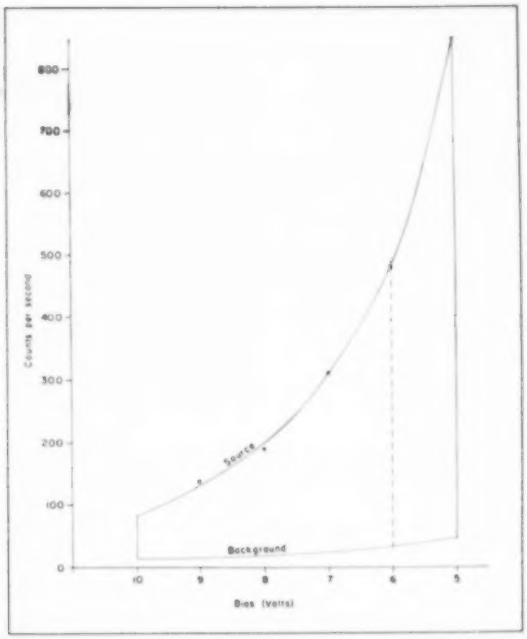

Fig. 7—Graph showing source to background relationships at different bias settings of the rate meter.

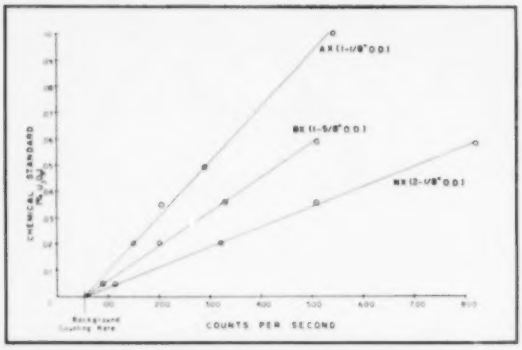

Fig. 8—Calibration curve, solid phosphor core scanner.

shielded chamber and the spacing between the surface of the drill core and crystal face are adjustable. Overall sensitivity is affected when the position of the scintillation head is altered and a new calibration must be established. In practice the sensitivity is adequate for the minimum activity in the smallest core studied and the position of the detecting element is usually maintained constant even though core diameters vary.

Calibration: There are many interpretations of sensitivity and calibration as applied to radiation-detecting equipment for geologic application. Spectral response, conversion efficiency from quanta to electrical energy of the sensitive element, signal-to-noise ratio and statistical fluctuation of counting rate are factors to be considered. Probably the most useful convention is an expression of counts per unit time ratio to a background or a standard counting rate, with source material and instrumentation specified. Such was the logic of calibrating the core scanner.

First a series of tests was made to determine how the combination of high voltage and discriminator bias affected the background counting rate of a given phototube and crystal assembly (Fig. 6). It is generally desirable to operate a photomultiplier tube at a voltage just below the dark current threshold for a given bias setting. In this case the operating voltage of 1160 v was selected. At higher voltages operation of the photomultiplier tube became erratic. Similar tests were made with a source located centrally in the counter chamber and the results were compared to the background counting rate to determine the bias setting for a particular high voltage (Fig. 7). Since an estimation of percent eU was made from the recorded results, operating conditions offering the greatest source to background count ratio were considered optimum. A bias setting of 6 v has been used with this equipment. Undesirable long-term drift characteristics in the input system of the rate meter ruled out lower bias voltages.

Artificial drill core samples of $1\frac{1}{8}$, $1\frac{5}{8}$, and $2\frac{1}{8}$ in. diam corresponding in size to AX, BX, and NX drill core were molded. A chemically analyzed pitchblende sample containing 64.5 pct U_3O_8, whose uranium was in equilibrium with its daughter products, was ground to 100-mesh size and mixed in different proportions with potters clay. Each mixture was split four times and water added to bring the mixture to a paste consistency. Samples 1 ft long were cast in plastic molds and allowed to harden. A second chemical analysis for uranium content was made after the samples were removed from the molds. A plot of percent U_3O_8 vs counting rate for each drill core size is shown in Fig. 8. These curves deviate from a linear function by ± 6 pct, which is within the operational error expected from experience with similar equipment. The range of percent equivalent uranium indicated is for subgrade ore material; however, any curve may be extended to include ore-grade materials containing as much as 10 pct eU_3O_8 and yet lie within the operational linearity of the equipment. Linearity depends primarily on the range of counting rate selected to indicate the equivalent uranium content. Chemically analyzed samples containing 1 pct U_3O_8 and no other radioactive constitutents are within the linearity stated when the high voltage and bias settings for data in Fig. 8 were used. For high grade ore of 1 to 10 pct eU_3O_8 a different high voltage and bias setting to reduce the overall counting rate should be selected. It should be pointed out that unless the equilibrium condition as well as the radioactive constituents other than uranium are known, a calibration in terms of uranium content is meaningless. Where equilibrium conditions, or other radioactive constituents, are not known results should be expressed in eU or eU_3O_8, which will be valid regardless of the state of equilibrium.

In addition to providing a fast semi-quantitative means of scanning drill core to determine the equivalent uranium content, the instrument has a practical use in other radiometric analysis. Crushed grab samples of drill cuttings may be sealed in pint-size cardboard containers equally spaced on the conveyor belt and run through the chamber to obtain readings of equivalent uranium content. Semi-quantitative results are achieved in this way with sample containing as little as 0.005 pct eU_3O_8.

Conclusions: A reliable and rapid method of scanning large amounts of drill core for radioactivity was constructed and proven in field operation. The drill core is scanned as it is automatically moved through a high-sensitivity chamber and a continuous graph of radiation intensity along the length of the core is plotted. Advantages of the equipment are simple and automatic operation, high sensitivity, and low long-term drift characteristics.

The authors are indebted to H. Faul and J. Rosholt of the U. S. Geological Survey, who gave freely of their time in technical discussions, and to J. Ohm and D. Hough of the USGS for mechanically constructing the instrument and assisting in experimental work.

The work reported here is part of an investigation carried on by the USGS on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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Discussion of this article sent (2 copies) to AIME before July 31, 1959, will be published in MINING ENGINEERING.

SME BULLETIN BOARD

Reports of Your Technical Society

DIRECTORY

SME's Membership Directory for 1959 will be bound into the July issue of MINING ENGINEERING

EDUCATION NEWS—633

SCHOLARSHIPS—631

MEETINGS . . .

For reports on the AIME Central Appalachian-SME Coal Division-West Virginia Coal Mining Inst. meeting turn to pages 625 and 626. For a picture story on the fourth annual Alaskan Mining, Minerals, and Petroleum Conference, turn to page 628.

EVERYONE

KNOWS. . .

That the Sphinx and Pyramids are among the "Wonders of the World." What are **your choices** for the "Mining Wonders of the World?" See page 638 for your chance to answer this question.

MEETINGS . . .

SME Members will be interested in the following meetings to be held this fall: the annual AIME-ASME Joint Solid Fuels Conference, October 27-29, in Cincinnati (page 622) and the joint Coal-Industrial Minerals Divisons' meeting, September 24 to 26, in Bedford Springs, Pa. (page 623). Preliminary plans are outlined in this issue.

Proposals for Membership

Change of Address Personals Data Boxes

These forms appear on page 634 for your convenience.

Mineral Information Section begins on page 572

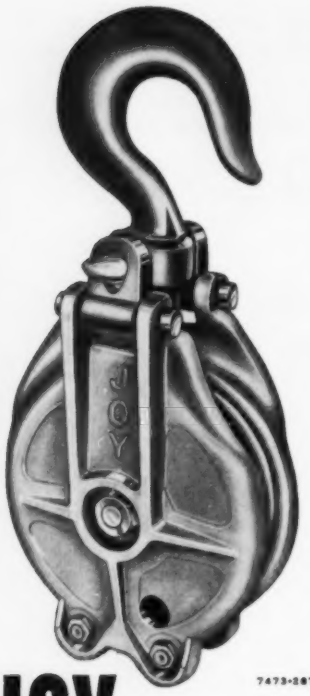
NEWSLETTERS . . .

• Coal page 625

• Rock in the Box page 627

Cincinnati Building Fund Goes Over The Top

Cincinnati is the first community in which all of its Founder Societies Sections have surpassed their quotas in full support of the United Engineering Center campaign. The total pledged now stands at $45,120. AIME does not have a Local Section in Cincinnati, but the Ohio Valley Section has also gone over the top. In the picture above, Ernest B. Fields, chairman of the Cincinnati Sponsor Group, receives a token of appreciation from Local Section representatives. Left to right are: Cornelius Wandmacher, ASCE; Julian E. Tobey, Ohio Valley Section, AIME; Ernest B. Fields; Lester L. Bosch, ASME; Kenneth H. Pettengill, AIChE; and Willard A. Farris, of the Cincinnati Section of AIEE. Other campaign news is reported on page 631.



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Rocky Mountain Assn. Plans Fall Symposium

The Rocky Mountain Assn. of Geologists is planning a symposium on the complete Cretaceous sedimentary section in Colorado and adjacent areas to be presented this fall in guidebook form.

A field trip will be held in conjunction with the symposium, October 7 to 10, 1959. This trip will begin at Saratoga Inn, Saratoga, Wyo., and will end on McClure Pass, between Grand Mesa and White River National Forests, near Carbondale, Colo. Emphasis will be placed on field examples in the Piceance and Sand Wash Basins of west-central and northwest Colorado, with a tie-in to the Washakie Basin Cretaceous exposures in south central Wyoming.

The guidebook will have a good coverage of the Cretaceous stratigraphy. The general purpose of the symposium is to stimulate a better understanding of this sedimentary section as to time and facies relationship.

David M. Evans is president of the Rocky Mountain Assn. of Geologists and can be contacted for further information at 414 C. A. Johnson Bldg., Denver 2, Colo. Fred S. Jensen is first vice president, Eugene M. Shearer is second vice president, John E. Deuth is secretary-treasurer, and counselors are Charles L. Severy and Gordon Hurd.

General chairman of the symposium and field trip committee is Robert K. Kretz.

Machinery Exhibition Scheduled For London

London will be host to an Exhibition of Mining Machinery from July 9 to 18, 1959, at the Grand Hall, Olympia. This will be the first exhibition of its kind in ten years, showing the latest developments in design and construction, plus ancillary equipment.

The Exhibition will be opened by the Rt. Hon. Lord Mills, K.B.E., Minister of Power. Visitors may obtain tickets at Olympia by presenting a business card. An Exhibition Catalogue listing the machines and manufacturers can be obtained on request from The Council of Underground Machinery Manufacturers, 301 Glossop Rd., Sheffield 10, England.

Australasian Meeting Convenes in August, '59

The Australasian Inst. of Mining and Metallurgy is presenting its annual conference from August 10 to 17 at Melbourne and Yallourn-Morwell, Victoria. G. L. Clark, president of the Institute, will welcome the registrants, along with the chairman of the Melbourne branch, H. F. King, and the chairman of the Latrobe Valley branch, Graham Black.

Divided into two sections, the conference will convene in Melbourne for business, technical, and social functions, plus visits to engineering works, oil refineries, educational and research establishments. The second section will include inspection of the activities associated with the brown coal deposits of Yallourn-Morwell, including mining, power production, solid fuel production, and gasification.

Arrangements have been made for members interested in geology and gold mining to include a short tour of some of the historical centers. In addition, a program for the ladies has been planned.

London Symposium Will Discuss Shaft Sinking

In conjunction with the Mining Machinery Exhibition scheduled for London in July, the Institution of Mining Engineers is holding an International Symposium on Shaft Sinking and Tunneling July 15 to 17, 1959. The technical sessions will be held in the Apex Conference Hall at Olympia. The symposium will be opened by Sir James Bowman, K.B.E., chairman of the National Coal Board.

Contributors to the conference include Australia, Canada, France, Germany, Poland, South Africa, and the USSR. Theoretical fundamentals of shaft sinking by the freezing method will be the Russian topic. Blasting practice and cementation will be discussed by British authors. Regional problems and developments will comprise the majority of paper subjects. For example, new shafts of the Dutch State Mines will be presented and shaft sinking and raising in Sweden will be discussed.

For further information contact The Secretary, The Institution of Mining Engineers, 3 Grosvenor Crescent, London S.W.1, England.

AIME-ASME Joint Fuels Papers Are In Progress

Program arrangements for the Joint Solid Fuels Conference are progressing under the leadership of J. E. Tobey, president, Appalachian Coals Inc., and H. E. Mauck, superintendent, Olga Coal Co. The conference is sponsored by AIME and ASME and will be held at the Netherland-Hilton Hotel in Cincinnati, October 27 to 29.

The selection of papers and speakers is of prime importance at this stage, and Mr. Tobey has been contacting top men for a paper concerning the long-range appraisal of

mechanized mining and has the promise of a paper on the preparation of coal for electric utility use.

Other suggested topics include bridging the gap between the coal producer and the consumer, and coal preparation to meet the requirements of industrial power plants. Coal preparation for the export market, and trends in rail movement for large coal consumers are also being considered for paper topics. The possibility of reduced freight rates makes this an important and timely concern.

A paper on the trends and developments in the drying of steam coals may also be added. Papers are due to be written and in the hands of Mr. Mauck by June 20 in order to be handled by the Papers and Publications Committee, or Review Committee. This early deadline is necessary for preprints, for session planning, program printing, and for other vital details.

Topics Are Considered For Bedford Springs

Planning for the Bedford Springs meeting this fall has reached the stage of choosing paper topics and lining up speakers. The joint conference of the Industrial Minerals and Coal Divisions will be held September 23 to 26 in Bedford Springs, Pa.

Acid mine waters is one of the problems to be considered. The dimension stone industry, underground storage as a national defense need, concerning limestone mines especially, and gypsum in Indiana, show the wide range of topics to be included. The comprehensive program will attempt to encompass the broad scope of interests that concern the two Divisions.

Under the heading of dimension stone many sidelights will be discussed. Competition of artificial dimension stone will be considered, and the economic health of the industry will be examined.

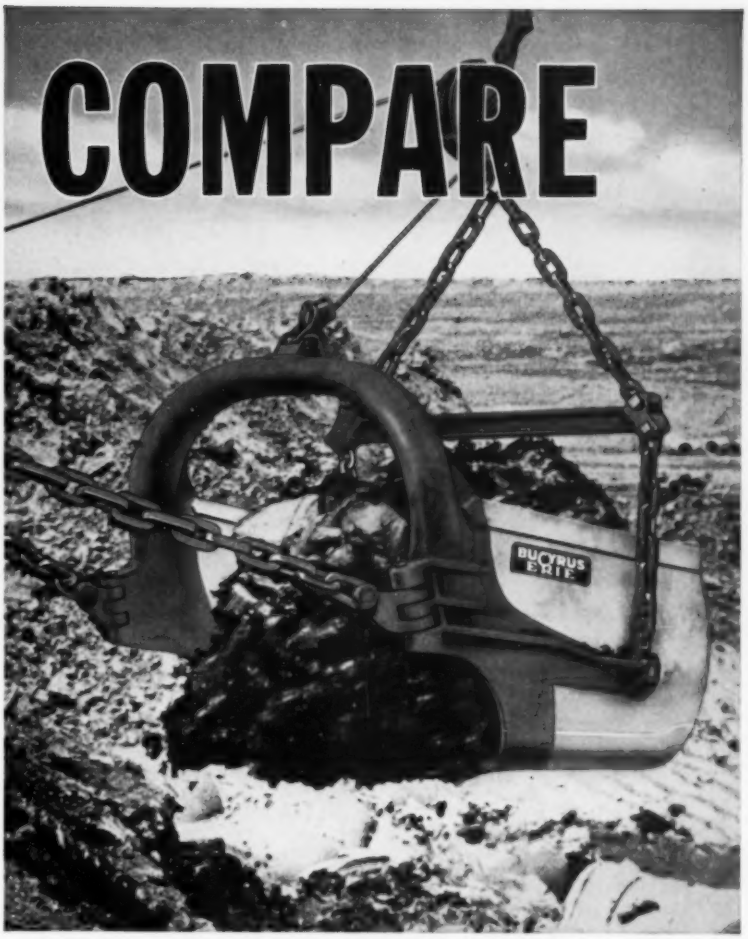
The problems of acid mine waters will be considered from the aspects of state controls, the influence of bacteria on the formation of acid mine drainage, and the mine effluent problem.

Chairman of the joint meeting is John J. Schanz, Jr., Pennsylvania State University, and Edward G. Fox, president of Bituminous Coal Operators Assn., is co-chairman. Program chairman for IndMD is Leon W. Dupuy, and H. Eugene Mauck is program chairman for the Coal Div. Contact these men with your suggestions for the conference.

International Congress Will Gather in London

The Institution of Mining and Metallurgy, London, extends an in-

(*Continued on page 630*)



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After test results were in, Jim Miner, general manager, W."Deck" Humphrey, mining engineer, and Bill Moman, foreman, had special praise for such features of the shuttle car as:

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Coal Men of West Virginia Combine Talents for Spring Meeting

A successful spring meeting of coal men was held in April through the combined efforts of the West Virginia Coal Mining Inst., the AIME Central Appalachian and Pittsburgh Sections, and the SME Coal Div. Gathered together at Mont Chateau Lodge on Cheat Lake, the conventioners attended technical sessions for two consecutive days at Morgantown, W. Va.

Technical Sessions

At 10:00 am on April 17 the first session got under way with co-chairmen Crawford L. Wilson, director of West Virginia Dept. of Mines, and H. E. Mauck, general superintendent, Olga Coal Co., at the helm. The opening paper was given by the state geologist, Paul H. Price, and was a progress report on the West Virginia mapping program. It was followed by the paper *Planning and Developing Moss No. 3 Mine*, Bill Stapleton, superintendent, Clinchfield Coal Co.

The final paper of the morning was presented by Robert S. James, USBM, on the subject *A Continuous Methane Monitoring System.*

Carel Robinson, chairman of the Central Appalachian Section, presided at the luncheon. He introduced Edward G. Fox, president of the Bituminous Coal Operators' Assn., as guest speaker. Mr. Fox discussed the effects of inflationary trends on the coal industry.

Productivity in the bituminous industry has increased 76 pct in the past ten years, Mr. Fox stated. Wage increases amount to 55.6 pct while coal prices at the mine have gone up only 2.5 pct. The phenomenal productivity gains allowed the industry to absorb wage costs up until now, but the rate of gain will be difficult, if not impossible, to maintain in the future. The recently negotiated $2 a day wage hike will demand a 6.75 pct productivity increase, which in turn demands more investment in machinery. And according to Mr. Fox the industry has reached the point where additional machinery does not significantly raise the output.

"We have held the price line in a highly competitive industry, both internally and externally, only by mechanization and, unfortunately, by attending the last sad rites of many companies unable to survive," he commented. With continued rising costs, this favorable trend is not likely to continue.

Mr. Fox also said that the long period without major strikes has helped the industry, and mechanization has improved safety factors, reduced lost time by accidents, and lightened heavy labor. We should not discount the genius of American business men, he added, in looking toward a strong future for coal.

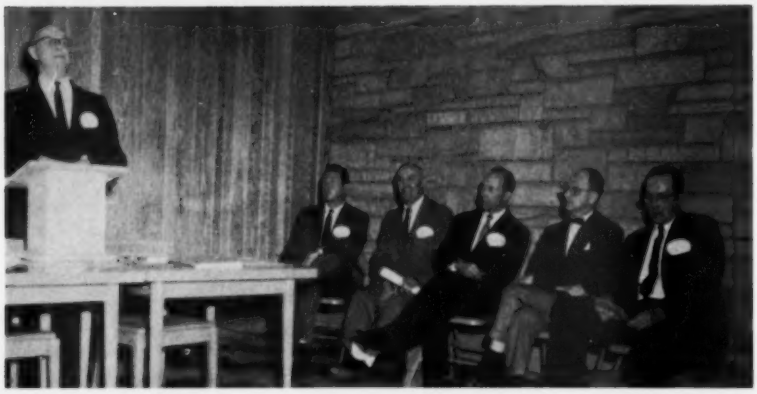
The afternoon technical session was opened by co-chairmen C. R. Bourland, president, The New River Co., and J. M. Vonfeld, chairman, Pittsburgh Section. A symposium on the preparation of coal fines was moderated by E. C. Carris, consulting engineer. Myron Mellor, McNally-Pittsburgh Mfg. Co., gave the first paper called *Feldspar Jigging* and Wendel Bearce, Hanna Coal Co., followed him with a discussion of froth flotation. *Horizontal Filtering* was the title of the next talk, by Mathew Turkovich, Island Greek Coal Co., and Robert Grimm, Inland Steel Co., talked about FluoSolids and desliming, closing the session.

A reception followed in the main dining room, before the informal dinner. R. G. Lazzell, president of West Virginia Coal Mining Inst., presided at the banquet. Featured on the program was the presentation of the Old Timers Club Award to a West Virginia University mining senior. Samuel M. Cassidy, vice president, Consolidation Coal Co., made the presentation. Then R. E. Salvati, chairman of the Coal Div., introduced the guest speaker for the evening, Elvis J. Stahr, Jr., who is president of West Virginia University.

On Saturday the technical sessions continued in the morning, with Stephen Canonico, vice president of Clinchfield Coal Co., as chairman. He introduced the first speaker, Stephen Krickovic, Eastern Gas and Fuel Assocs., who presented the paper *Automatic Skip Hoisting at Federal No. 1.* A symposium followed, moderated by Neil Robinson, mining consultant. The topic covered *Main Line Haulage with Track and Conveyor Belt Systems.* William Husk, West Kentucky Coal Co., discussed conveyor belts, and Eugene Ruttle, Mathies Coal Co., covered track haulage. Their presentation completed the technical conference.

(Continued on page 626)

Featured speakers and officers of the spring coal meeting pose in the sun at Mont Chateau Lodge. At left is Raymond E. Salvati, chairman of the Coal Div. Next to him is R. G. Lazzell, president of West Virginia Coal Mining Inst., who presided at the dinner, and C. R. Nailler, executive board member of the Institute. On the right is Edward G. Fox, who spoke at the luncheon.



(Continued from page 625)

On top, these jovial speakers took part in the Friday morning session and are photographed here with J. W. Woomer, SME President, right. Facing the group is Crawford L. Wilson, session co-chairman, speaking to Paul H. Price, West Virginia state geologist and Robert S. James, USBM. In the picture at the left, the speakers of the Friday afternoon technical session are seen waiting their turn, while C. R. Bourland, president of The New River Co., and co-chairman of the session, introduces them. Sitting attentive from left to right are Myron Mellor, Mathew Turkovich, Wendel Bearce, Robert Grimm, and Mr. Davis.

Seen at the left, standing at the podium, is Samuel M. Cassidy, vice president of Consolidation Coal Co., who presented the Old Timers Club Award to a West Virginia University mining engineering senior. Standing to his right are Mr. and Mrs. Louis Murphy, who received the honor. Mrs. Murphy works for Christopher Coal Co., helping put her husband through college. Gathered around the conference table at the right are speakers for the Saturday session who presented papers and a symposium under the chairmanship of Stephen Canonico. From the left corner are Eugene Ruttle, Mathies Coal Co.; Stephen Krickovic, Eastern Gas and Fuel Assocs.; Mr. Canonico; Neil Robinson; William Husk and Mr. Poundstone. The symposium covered the topic of main line haulage.

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ROCK IN THE BOX

Mining & Exploration Division

"LETTERS TO EDITOR" BRING MEETING REPORTS TO M&E'ers

Many M&E members do not have an opportunity to attend all the professional and technical meetings held throughout the year in the U. S. and other parts of the world—for example, recent meetings in Canada. The following letters give M&E'ers first hand reports on some of these conferences.

Dear Mr. Chandler:

As an American engineer living in Canada, I feel that the annual meeting of the Prospectors and Developers Assn. held during March in Toronto, and the annual meeting of the Canadian Inst. of Mining and Metallurgy, held during April in Montreal, were both outstanding conventions, and that the attention of those in the AIME who may not be familiar with these meetings, should be directed to them.

The papers given at the Prospectors and Developers Assn. convention are aimed primarily at prospecting and exploration and give an excellent review of current activities, new techniques in use, and exploration results across Canada. Of particular interest this year was a symposium on *Canadian Exploration Techniques* in which the panelists answered the following pertinent questions: 1) How do you select an area for exploration? 2) What do you regard as the role of the prospector in exploration today? 3) How do you organize a prospecting program? 4) What is the proper role of airborne electromagnetics and airborne magnetometer surveys as reconnaissance tools? 5) What do you recommend as a ground follow-up program after an airborne geophysical survey?

The Canadian Inst. of Mining and Metallurgy is comparable in many ways in its make-up to the AIME and the papers presented cover subjects in the fields of metal mining, geology, geophysics, metallurgy, industrial minerals, coal and petroleum and natural gas. A symposium on *A Great Canadian Enterprise—Gaspe Copper Mines Limited*, presented by members of the Gaspe Copper staff, was of interest to all. Another symposium on *Handling and Placement of Hydraulic Backfill Underground* received very favourable comment from many mine operators and engineers. A third symposium was of great interest to the geologists present. It dealt with massive sulphide deposits and was presented in three sessions, *Massive Sulphide Occurrences in Canada; Exploration for Massive Sulphide Deposits;* and *Genesis of Massive Sulphides.*

It should be noted that both conventions established new attendance records this year, and that there was a representative group of visitors from the United States at both meetings, who, I am sure, felt that the meetings were very much worthwhile from the standpoint of new ideas, new perspectives, and new contacts.

Yours very truly,

Keith Whiting
Managing Director
Asarco Exploration
Co. of Canada Ltd.

Other comments concerning the CIM meeting in Montreal came in a letter from Richard M. Stewart and again emphasize the value of the technical sessions. Mr. Stewart also reported on the Symposium on Rock Mechanics at The Colorado School of Mines held at Golden, Colo.

Dear Mr. Chandler:

I am enclosing a paper which I read as an introduction to the panel discussion on *The Handling and Placement of Hydraulic Backfill Underground.* The chairman of the panel was W. S. Row, president, Kerr-Addison Gold Mines Ltd., and members of the panel were: E. G. Grayston, general manager, Madsen Red Lake Gold Mines Ltd.; T. M. Gaetz, manager of mines, International Nickel Co. of Canada Ltd.; C. T. Girdwood, general manager Domes Mines Ltd.; W. B. Montgomery, general manager Pioneer Mines of B. C. Ltd.; R. M. Stewart, assistant director of mining research, The Anaconda Co. I am also enclosing a copy of the questions which were submitted to the panel for their consideration prior to the discussion period. We spent nearly four hours reviewing these questions prior to the panel discussion and as a result of this I missed most of Monday's Institute sessions. These questions were planted on the floor and were asked essentially in the order indicated. The answers were recorded on tape and will soon be published in the CIM Bulletin.

I think the most important trends that came out of the session were the increased use of boreholes rather than pipelines for transmission of hydraulic fill slurries and the use of underground sand storage facilities together with a greater appreciation of the phenomenon of flow of thick slurries in pipe lines.

I am enclosing a program of the third Symposium on Rock Mechanics. This gives a short biographical sketch of the authors together with an abstract of the material covered in their papers . . . The Proceedings of this Symposium will be available from the Department of Publications, Colorado School of Mines, Golden, Colo., as a quarterly. I would expect it to be completed in two or three months.

One of the major contributions to the Montreal meeting was a symposium on *A Great Canadian Enterprise—Gaspe Copper Ltd.* This included papers on the geology, mining, concentrator operations, smelting, engineering services, and the planning of the town of Murdockville.

Yours very truly,

Richard M. Stewart
Assistant Director,
Mining Research

One of the main advantages of AIME membership is the opportunity to attend meetings of this caliber. Our own Local Section meetings have this quality of technical presentation although on a smaller scale, a recent letter from Joseph F. McAleer attests.

(*Continued on page 633*)

EDITOR

Address news items to:

John W. Chandler, American Metal Climax Inc., 61 Broadway, New York 6, N. Y.

A BRIGHT FUTURE FORECAST FOR ALASKA

A. C. Beguin discusses asbestos mining at the 1st session Friday morning, April 3.

Robert W. Vinnedge is next above, discussing platinum, and C.D.N. Taylor, below, closed the morning session.

The Fourth Annual Mining, Minerals, and Petroleum Conference was held at Anchorage, Alaska, April 3 to 5, sponsored by the AIME Alaska and Southwest Alaska Sections, and the Yukon Section of the Canadian Institute of Mining and Metallurgy. Registration began at the Westward Hotel and technical sessions were held in the Loussac Library.

Harold Strandberg was general chairman of the conference which welcomed more than 200 visitors and native Alaskans to the sessions, dinners, and field trips. Joseph Homer was chairman of the AIME Section meetings staged in connection with the convention.

Friday morning opened the technical sessions with Hugh Matheson as program chairman. Five papers were presented before noon, including *Sled Transportation of Heavy Single Loads in Interior Alaska* by Richard S. Ludwig and *Geology of Iron Creek Area* by Kirk Stanley.

The welcoming luncheon featured Erik Neilsen, member of the Canadian Parliament from the Yukon Territory, who spoke on Canadian-U. S. relations regarding negotiations on development in the Pacific Northwest. He discussed specifically a bill introduced in the Senate for paving the Alaska Highway. Since there were no government-to-government talks on the project prior to introduction of the bill, Canada now finds the terms unacceptable.

In the afternoon, Jack Crooker was the program chairman, introducing five speakers including J. C. Hoffman and W. E. Whitney. Mr. Hoffman spoke on geophysical exploration in Alaska; Mr. Whitney discussed drilling principles and equipment.

A dinner that evening was held at the Forest Park Country Club for registered guests and their wives.

On Saturday Leo Saarela opened the session by introducing C. F. Herbert who gave a legistative report. Then C. L. Sainsbury gave an address prepared in collaboration with Reuben Kachadoorian entitled *Geologic Factors Affecting Proposed Nuclear Harbor at Northwest Alaska.*

Featured speaker for the luncheon was Ernest N. Patty, president of the University of Alaska. Dr. Patty challenged the oil industry to develop as quickly as possible the rich potential of the new state in order to protect the nation against the loss of foreign oil interests.

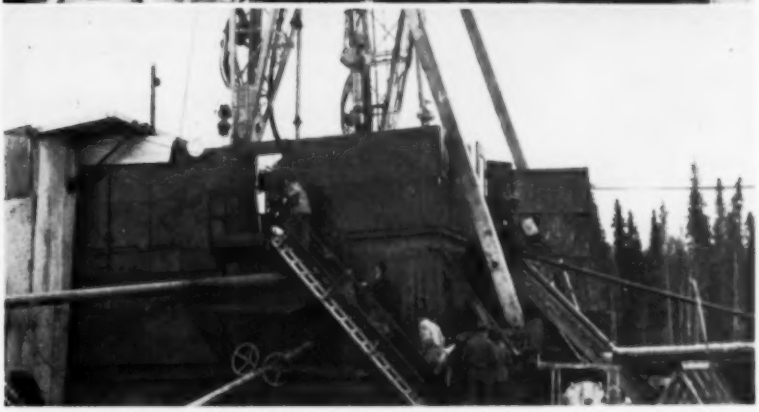
The afternoon session was led by Douglas B. Colp and included papers by Troy L. Pewe on *Permafrost and Its Effect on Life in the North* and George Gryc on petroleum exploration. Phil R. Holdsworth also spoke on *State Selection of Land and Its Effect,* and other session speakers are seen in the on-the-spot photos.

The final banquet Saturday night was semi-formal, held at the Idle Hour Club. Michel T. Halbouty, guest of honor, promised a bright oil future for Alaska: "You will live to see Alaska one of the greatest oil producing areas in the world."

Two field trips on Sunday climaxed the convention, with free transportation and lunch provided by Evan Jones Coal Co. for a tour of the Upper Matanuska Valley coal mine district. Wiley D. Robinson conducted the tour through the mines. A second trip, pictured here, included the Swanson River field, under the guidance of Leo H. Saarela. In addition, the ladies attended a special luncheon at the Club 25 on Saturday, joining the men for the rest of the program.

Addressing the Saturday evening banquet in the corner picture is Michel T. Halbouty. Greeting the luncheon speaker, above, Harold Strandberg (left) shakes hands with Erik Nielson, while Joseph Homer, A. C. Beguin and W. W. Desrosiers watch.

Speakers at the second session, Friday afternoon, are seen above. George R. Gray, left, discusses drilling mud function. In the center R. J. Misbeek is talking about oil well logging methods. And at the right, top, Joe Fehrenbach lectures on drillstem testing techniques. These three oilmen are from National Lead Co., Richfield Oil Corp., and Halliburton Oilwell Cementing Co., respectively. Seen at the right are two officials of the Humble Oil and Refining Co. One is a session speaker, T. A. Huber, left, who addressed the Saturday morning meeting on oil and gas production. The other is chairman of the Southwest Alaska Section, host Joseph Homer.



Above left are two of the speakers at the final session. P. O. Sandvik is talking about regional structrual control of mineralization in Alaska, and below him H. B. Keller is speaking on nuclear explosives in the mining industry. At the right, above, members of the conference are touring the Swanson River field where current drilling is conducted by the Standard Oil Co. of California.

Future ASME Meetings Open to Sister Groups

The American Soc. of Mechanical Engineers has opened its future meetings to all members of the 21 sister engineering societies within the Engineers Joint Council or Engineers' Council for Professional Development.

A statement by Glenn B. Warren, president of ASME, explained why engineers will now be charged the same registration fee that ASME members pay or will attend general meetings without registration fee.

"We hope that, by taking this initial step, ASME is helping to demonstrate the community of interests shared by all engineers and is helping to lead the way toward greater liaison at the working level. Clearly, many of ASME's national meetings are of interest to members of our sister groups. We hope that the adjustment of registration fees will encourage them to share in the benefits of these meetings and conferences. Although this step may result in some loss of income to ASME, we are confident that dollars spent in this way will pay dividends for the entire profession."

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ASS'T TREASURER JOHN LYNCH

AIME NEWS

Creation of Cabinet Dept. Supported By EJC

Engineers Joint Council, representing more than a third of the nation's engineers, solidly backed the creation of a Cabinet-level Department of Science and Engineering, in a statement before the Subcommittee on Reorganization and International Organizations of the Senate Committee on Government Operations at a Washington hearing April 16. EJC was represented at the hearing by Enoch R. Needles, president, and Augustus B. Kinzel, vice president of the organization.

New demands being made of government, industry, and higher education, plus the widening activities of engineering, make it necessary to establish responsible leadership in government to develop an efficient long-range program for science and engineering. "Under the current diversity of organizational effort there is real danger that important areas of new knowledge will not receive the attention and research support they merit," Mr. Needles concluded. The purpose of the department would be to develop balanced programs, prevent dissipation of efforts, and insure the preservation of U. S. excellence in fundamental areas of science and engineering.

International Congress

(*Continued from page 623*)

vitation to AIME members to attend the International Mineral Processing Congress in April 1960. It will be held at Church House, Westminster, London, from April 6 to 9.

The Congress will be the fifth in the series of international gather-

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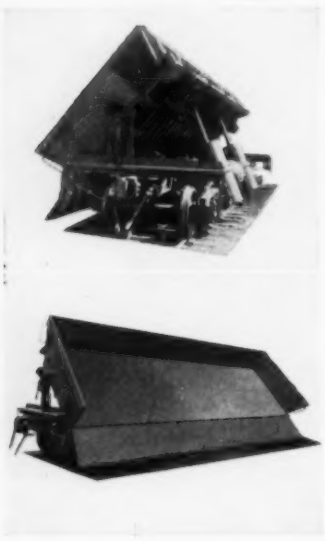

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ings to discuss mineral processing problems, which began with a meeting in London in 1952, and has included conferences in France, Germany, and Sweden. Papers of the greatest technical interest have been presented, and engineers and scientists working in this field have exchanged ideas during informal gatherings.

The scope of the Congress will include fundamental and applied research and development in the fields of mineral dressing and chemical processing, excluding smelting.

A special feature will be the Sir Julius Wernher Memorial Lecture, presented by I. W. Wark, chief of the Div. of Industrial Chemistry, Commonwealth Scientific and Industrial Research Organization, Australia.

All Congress proceedings will be in French, German, and English by means of simultaneous translation. Preprints of papers, and the final volume of proceedings, will be published in English.

Plans are being made for members to have an opportunity to visit areas of the United Kingdom of particular interest during the week following the Congress. A special program for visiting ladies will also be arranged.

Thomas Cook and Son Ltd. has been appointed travel agent for the Congress. Members are encouraged to contact them without delay. A fee of approximately $14 will be made for Congress membership, $7 for ladies accompanying members, and $7 for students. Additional charges will be made for visits and excursions. All registered members will receive, without further charge, preprints of papers to be discussed.

For all additional information please address correspondence to: The Secretary, The Institution of Mining and Metallurgy, 44 Portland Place, London W. 1, England.

Scholarships

Colorado School of Mines

The First National Bank in Golden, Colo., has made its third contribution of $1000 to the Colorado School of Mines as an unrestricted donation. The Colorado School of Mines Foundation Inc. is a private organization which receives contributions for its Horizon Plan, a long-range blueprint of the future for the college. The Foundation will use this contribution for the faculty improvement plan.

• A $3000 contribution from the Ensign-Bickford Foundation Inc. will be used by the School of Mines for payment of a digital computer,

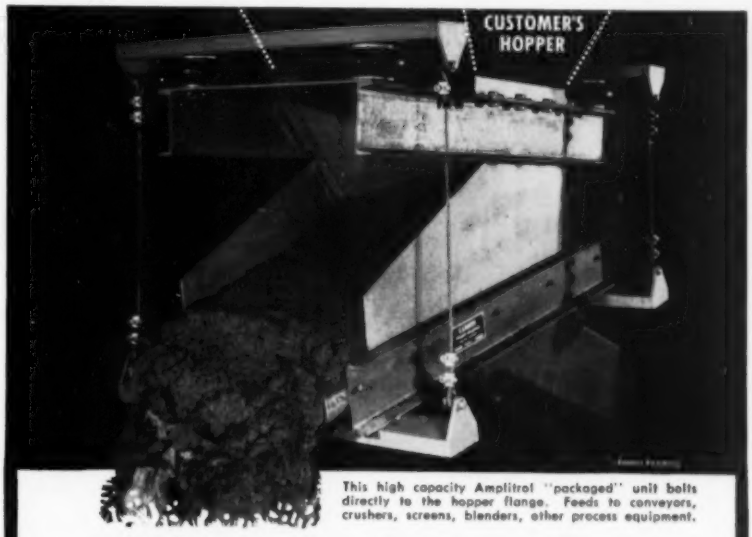
(*Continued on page 633*)

AIME PASSES HALFWAY MARK IN GIFTS CAMPAIGN UNITED ENGINEERING FUND PASSES 75 PCT POINT UET SETS WORKING SCHEDULE FOR CONSTRUCTION

A tentative working schedule for the construction of the new United Engineering Center was adopted by United Engineering Trustees Inc. on April 23. The deadline for completion of working drawings is Aug. 30, 1959. Shreve, Lamb, and Harmon Assoc., the architects, are cooperating with Stevenson, Value & Knecht, structural engineers, and Jaros, Baum & Bolles, mechanical engineers.

Construction should begin Oct. 15, 1959. The building construction is scheduled for completion by Mar. 15, 1961. The completion of requirements for occupancy will be July 1, 1961.

The adoption of this construction schedule gives a sense of urgency to the attainment of the subscription quotas in the Industrial and Member Gifts Campaigns at the earliest possible date.



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"Feeder-Hopper Bottom Package" Reduces Design, Installation Costs!

For the first time a feeder is offered as part of a complete pre-engineered feeder-hopper bottom package. When you design with Carrier Amplitrol feeders, you merely design a hopper flange to bolt to the packaged unit. *This saves you both engineering design and installation costs!*

This preassembled packaged unit is built around the revolutionary new Amplitrol feeder — first mechanical vibrating feeder with variable, stepless control—and includes the hopper bottom, flanged hopper connection, skirt plates, regulating gate, isolation and suspension supports.

The feeder-hopper bottom unit is offered in two models—one for *high capacity* applications and one for *maximum control.*

Amplitrol's exclusive long-stroke drive handles higher capacities by automatically compensating for headload. This allows larger hopper openings, reduces bridging and hang-up. The simple, fast-responding pneumatic control system operates manually or in automatic response to any standard process instrumentation.

Send for new Bulletin No. 591 describing Amplitrol "package" in detail. Carrier Conveyor Corporation, 252 North Jackson Street, Louisville, Kentucky.

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Around the Sections

• The **Morenci Subsection**, Arizona Section, met at the Longfellow Inn on March 10. The program included a color film by the Geological Survey on the eruption of Kilauea on the island of Hawaii.

• The Spring meeting of the **Pennsylvania-Anthracite Section** was held in Hazleton on April 10. D. C. Rubert presented the paper: *Can Hydraulic Mining Be Applied to the Extraction of Anthracite*, and Walter Haentjens gave his paper on *Slurry Pumping*.

• The annual joint meeting of the **Montana Section** and the Montana Soc. of Engineers was held in Anaconda on March 21, with the Montana Section as host. A social hour and dinner preceded a talk by George Hale on his travels to Andean mining properties.

• The **Mexico Section** meeting for March featured a report on the Annual Meeting by Salvador Pena, and an illustrated lecture by Guillermo P. Salas on *Los Depositos De Bauxita en Haiti y Jamaica*.

The Mexico Section discussed the progress of the three students who are receiving Section aid and the replacement of the two who will finish this year, at their April 13 meeting. Guest speaker for the evening was Luis de la Pena Porth.

• The 1959 officers of the **Adirondack Section** are: Charles Dievendorf, chairman; Severn Brown, vice chairman; George Erdman, secretary-treasurer; Brower Dellinger, program chairman; David Crawford, membership chairman; and Eugene Eastman, students affairs chairman.

• The Annual Career Forum of the **Pennsylvania State University Student Chapter** was held on April 6 in the Mineral Science Auditorium. Opportunities in their specific areas were discussed by the guest panelists: *P. A. Burns*, manager of product sales, Hewitt-Robins Inc.; *H. C. Houghton*, assistant personnel manager, Bethlehem Steel Corp., *L. Obert*, chief, Applied Physics Laboratory, U. S. Bureau of Mines; *W. J. Parton*, vice president of operations, General Crushed Stone Co.; and *C. B. Tillson*, assistant manager, Fuel Div., Crucible Steel Corp.

• A field trip through the Rolla, Mo., area to examine the geological features of the Ozarks preceded the April 11 meeting of the **St. Louis Section**. Roy E. Mayes, president, Carthage Marble Corp., described quarrying operations and marketing factors of the marble industry.

• Members of the **Southern California Section Mining Group** were photographed on a field trip to Eagle Mountain last December 20 when they visited Kaiser Steel Corp.'s mining operation.

• The **Pittsburgh Section Mineral Industry Group** held a dinner meeting Jan. 21, 1959, at the Gateway Plaza Restaurant, Pittsburgh. The guest speaker was S. J. Shale and his subject was *Discovery and Development of Pennsylvania's Newest Metal Mine—The Grace Mine*.

• On Feb. 28, 1959, the **Wyoming Mining and Metals Section** held a meeting at Laramie, Wyo., with a tour of the Wyoming Research Inst. on the campus of the University of Wyoming. An evening dinner program at the Diamond Horseshoe Restaurant featured Frank Mockler, Fremont County Senator, for a discussion of the state legislature program.

• The **Southwest Alaska Section** meeting for March was held at Thompsons Cafe in Anchorage on the 16th. Plans for the annual forum were discussed, and a talk on the *Cooper Lake Hydro Project and Power Outlook* provided lively discussion. Robert Rutherford was the guest.

• Through both film and narration R. K. Johnson of Western-Knapp Engineering Co. presented the story of a new modern smelter at the **San Francisco Section** meeting April 8. Mr. Johnson played an active part in the construction of Kennecott Copper Co.'s smelter at Hayden, Ariz.

• A regular dinner meeting of the **Colorado Section** was held April 16 at the University Club in Denver. V. Wessels gave a history of the Ideal Cement Co., including the most recent developments.

• The **Bisbee-Douglas Subsection**, Arizona Section, welcomed seven high school students interested in mineral engineering for college study. Ed Torgersen, Phelps Dodge Corp., outlined the benefits of the Institute and careers in the industry. The meeting took place Feb. 28, 1959, in Naco, Ariz.

• The **Lehigh Valley Section** held its annual spring dinner meeting April 24 at the Hotel Bethlehem, Bethlehem, Pa. Nathan Brown presided and Warren S. Moore discussed mining in Alaska.

Guests seated at the head table for the Wyoming Mining and Metals Section dinner on February 27 are, left to right: Henry Fisk; Frank Mockler (standing), Senator; J. W. Joyce, chairman; and I. M. Charles. In the group shot at the right the adventurers of the Southern California Section Mining Group pose on the site of Kaiser Steel's mining operation at Eagle Mountain, Calif.

Education News

University of Arizona

James D. Forrester, dean of the College of Mines at the University of Arizona, has been urging Arizona high school graduates to consider careers in the minerals industry. He explained that he has been experiencing difficulty in accommodating requests from mining firms for qualified engineers. "The shortage appears to be particularly acute in the fields of mining engineering and metallurgical engineering. The salaries being offered to fill positions are excellent and the opportunities for advancement of competent and qualified men are outstanding."

• The College of Mines was host to the 55th annual meeting of the Cordilleran Section of the Geological Soc. of America on April 2 to 6. The meeting was the occasion for an open house to present the new geology wing of the combined mines-geology structure. F. W. Galbraith, head of the geology department, was the program chairman in charge of the technical sessions. Highlights were a symposium on *Cenozoic Geochronology in the Western States*, and a symposium on *Hydrology of Arid Lands*.

Colorado School of Mines

The patent model for the Fowle drill, the first mechanical drill used in the U. S., has been donated to the School of Mines by Maxwell L. McCormack, special representative for the Ingersoll-Rand Co. The drill received a patent in 1851 when all patent requests had to be accompanied by a scale working model of the invention.

Rock in The Box

(*Continued from page 627*)

Dear Mr. Beals:

The Montana Section, AIME, held its monthly meeting on April 21, 1959, in the Petroleum Engineering Building at Montana School of Mines in Butte with chairman J. J. Dougherty of Anaconda presiding.

The main purpose of this meeting was to hear the always interesting Arthur Linforth, retired assistant to the vice president in charge of Western Operations, The Anaconda Co., speak about his lifetime hobby. In his talk entitled *The Adventures of a Model Maker*, Mr. Linforth related several entertaining historical anecdotes that centered around some of the three-dimensional models he has made. One of these included the time M. Linforth was engaged by both the plaintiff and the defendant to construct mine models to be used in presenting their respective cases in some of the early Butte litigation. This evoked a later comment that the engineering profession was truly an honorable one when both parties in the case entrusted their model making work to the same man.

Of Mr. Linforth's most recent efforts, undoubtedly the well traveled model of the Chuquicamata plant, pit, and ore deposits is the best known.

Very truly yours,

Joseph F. McAleer
Geologist
The Anaconda Co.

Scholarships

(*Continued from page 631*)

to enable the school to move ahead in mathematical areas concerning mineral study and research. The Ensign-Brickford Foundation Inc. manufactures safety and primacord detonating fuses in Simsbury, Conn.

• The Morse Brothers Machinery Co. has made its third contribution of $1000 toward a $5000 pledge made several years ago. John W. Vanderwilt, Mines president, stated the money would be used to support research performed by the Research Foundation of the Colorado School of Mines.

Photo - Courtesy, United States Steel Corporation.

Tough cars for a big job . . .

In 65 years or so the first dipper hole at Mesabi has grown to the tremendous open pit pictured here in part. Differential Air Dump Cars first put in appearance at Mesabi in 1925. Veterans of many years and thousands of tons, these cars have carried their loads uncomplainingly. Steady reorders have a pleasant way of nodding approval. We would be glad to tell you more about Differentials — how they're made and why you'll like them.

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Personals

T. B. COUNSELMAN

H. F. YANCEY

T. B. Counselman, former vice president of AIME, has been elected councillor of the Mining and Metallurgical Soc. of America, and president of Columbia University Engineering Schools Alumni Assn.

The North Pacific Section announced that its nominee, **Harry F. Yancey,** was chosen as *Engineer of the Year* by the Seattle Chapter of Washington State Professional Engineers and the Puget Sound Engineering Council. The award was made at the annual banquet in Seattle. Dr. Yancey is head of the U. S. Bureau of Mines Experiment Station at the School of Mineral Engineering, University of Washington.

Phillip M. Vince is in Antofagasta, Chile, working as mine superintendent for Samincorp. He had been assistant mine superintendent for Chile Exploration Co. with his home in Salinas, Calif.

S. Z. Respicio, Jr., has left Ind. & Business Management Corp. where he was a mining engineer and geologist. Now he is mine foreman for Benguet Consolidated Inc. in Baguio City, Philippines.

J. M. McShane has resigned as managing director of Australian National Industries and is now company director.

William G. Freeman, formerly assistant mine foreman for Cerro de Pasco Corp., now is geological engineer for Milwhite Mud Sales Co. in Houston.

William G. Fischer is mining engineer with International Chemical Co., West Vaco Chlor-Alkali Div. of Food Machines & Chemical Co.

Edgar von Bolhar has resigned after 25 years with Yuba Manufacturing Co. in San Francisco. During his career he was chief engineer, director of research and developments of Yuba Industries, and finally director of engineering, Mining Div., Yuba Consolidated Industries. He has become chief of design for Ellicott Machine Corp. in Baltimore.

M. M. O'Brien, for many years managing director of Bralorne Mines Ltd., has now assumed the position of consulting engineer of the new Bralorne Pioneer Mines Ltd. in Vancouver, B. C., Canada.

M. M. O'BRIEN

S. WESTGARD

Sherman Westgard, superintendent of copper refineries of the Great Falls, Mont., reduction department, The Anaconda Co., has been appointed superintendent of copper refineries, Raritan Copper Works, International Smelting & Refining Co., Anaconda subsidiary in Perth Amboy, N. J.

PROPOSAL FOR AIME MEMBERSHIP

I consider the following person to be qualified for membership and request that a membership kit be mailed to him:

Name of Prospective Member:

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Address

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Name of AIME Member:

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SME

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CHANGING YOUR ADDRESS? Don't forget to notify us six (6) weeks before you move, if possible, to insure uninterrupted receipt of your publications and correspondence. Please fill in the form below and send it to: J. F. Lynch, Asst. Treasurer AIME, 29 West 39th Street, New York 18, N. Y.

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Old Address .....

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PERSONALS: Please list below your former company and title and your new title and company (or new work) for use in MINING ENGINEERING. (Copy deadline for personals items is six weeks before date of issue.)

Former Company .....

Former Title ..... Length of Time There .....

New Company .....

New Title ..... Date of Change .....

.....

Any recent activity that would be of interest to members:

.....

.....

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Ray M. Henricksen, formerly construction engineer for Kennametal Inc., now is associated with A. R. McGuire in consulting geology and mining in Fallon, Nev.

Robert A. Metz has transferred from the Chino Mines Div. of Kennecott Copper Corp. where he was assistant geologist, to the Ray Mines Div. where he will be senior geologist. He has moved from Santa Rita, N. M., to Ray, Ariz.

The St. Joseph Lead Co. elected **Joseph Pursglove, Jr.,** to the board of trustees. Mr. Pursglove is vice president of research and development of Consolidation Coal Co., Pittsburgh. He is responsible for the largest research program ever undertaken by a single coal company. Other elections were: **James G. Colvin**, formerly comptroller and assistant treasurer, now treasurer; and **William L. Murphy, Jr.,** formerly assistant comptroller, who became comptroller.

Blair W. Stewart, prominent mining executive, has joined the executive staffs of American Mineral Co. and Desert Minerals Inc. He was elected president of American Mineral Co. and vice president and treasurer of Desert Minerals Inc., and a director of both. He has served as president and vice president of various mining subsidiaries of Cyprus Mines Corp.

K. S. HOBBS

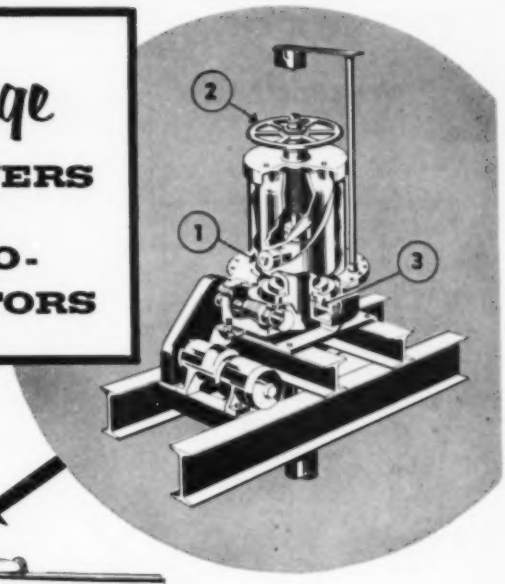
C. O. CARMAN

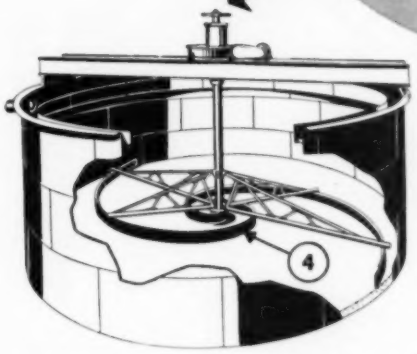
Six personnel changes were announced by Eastern Gas and Fuel Assocs. that took effect March 1. **K. S. Hobbs** was appointed superintendent of Stotesbury No. 10 and No. 11 mines in West Virginia. **C. O. Carman** was named production engineer of the Low Volatile Div. **C. J. Kirby,** superintendent of the Stotesbury Nos. 10 and 11 mines, has been granted a leave of absence. **Donald W. Hunter,** production manager at Eastern's Sonman mine in central Pennsylvania, has been named resident engineer at the Wharton No. 1 mine at Wharton, W. Va. **John P. Baugues,** who has been the resident engineer there, was transferred to resident engineer at Federal No. 1 mine near Fairmont, W. Va. And **Frank W. Riddle,** who was the resident engineer at Fairmont, has been placed on the chief engineer's staff in Pittsburgh.

Fred T. Agthe, consulting engineer for Allis-Chalmers Manufacturing

Hardinge

THICKENERS and HYDRO-SEPARATORS



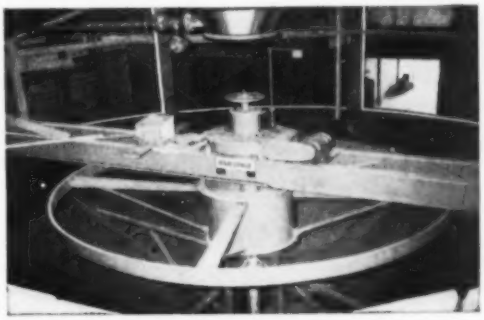


. . . for all clarifying, thickening and de-sliming operations.

For flotation concentrates thickening ahead of filtering—or for tailings disposal or reclamation, Hardinge Thickeners provide:

1. "Auto-Raise" to avoid lost production from overloads.
2. Manual or power raise to supplement "Auto-Raise."
3. Replaceable ring-type ball bearing support for rotating mechanism.
4. Spiral rakes for maximum underflow density.

Also available are froth rakes for froth-free overflow and superposed type tank construction for minimum floor space and building economy. Complete specifications on request. Bulletin 31-E-2.



A 35'-diameter Hardinge Superposed Thickener installation in a Canadian lead-zinc concentrator. The sludge outlet for the upper unit can be seen at the top of the picture. Note froth ring on lower unit.

HARDINGE COMPANY, INCORPORATED

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personals

continued

Co., has been named *Engineer of the Year* by the Engineers' Soc. of Milwaukee. His present position is the culmination of 35 years with the Allis-Chalmers engineering cement plants and developing processes for grinding, burning, and other plant operations.

John T. Whiting, chairman of the board of Alan Wood Steel Co., is celebrating the completion of 50 years service in the steel industry. Under his direction, financial reorganization, and modernization program, the company has enjoyed its greatest period of growth.

E. W. Douglass has been doing consulting work in potash for the past four years and is presently on assignment with the United Nations Technical Assistance Administration as a consultant for the Arab Potash Co., working toward the production of potash from the brine of the Dead Sea.

Walter F. Meckel, formerly mill superintendent for Cerro de Pasco Corp., has been visiting copper operations in Arizona and Nevada gathering data for construction of a new plant in Antofagasta, Chile, where he is employed by Empressa Minera de Mantos Blancos as general manager of operations.

Norton Jackson has recently made a tour of the Philippine mining fields as technical representative of American Cyanamid Co.

Herbert Fleishman, formerly resident manager of Istanbul Mangan Turk Ltd. Sirketi, now is treasurer of Fleischman, Burd & Co. Inc. in New York. He supervised the company's mining interests in Turkey.

Ralph L. Miller, formerly chief of Fuels Branch, U. S. Geological Survey, now is technical advisor to the Mexican Geologic Inst. for U.S.G.S. and International Cooperation Administration. In 1958 he assisted the government of Afghanistan in drafting a mining law and petroleum law.

Richard H. Willey, formerly project manager for Camagra Mineral Exploration, now is general manager for Nickel Processing Corp., Nicaro, Cuba.

A new firm, Exploration Services Inc., has been established for Alaskan exploration for minerals, petroleum, and for market potential surveys. **Ted C. Mathews** is president of the firm, with 20 years experience in mining, petroleum exploration, and private consulting. He has been director or Arctic Research Laboratory for the University of Alaska. **James A. Dalton** is secretary, with experience in petroleum exploration and construction. The vice presidents are **Douglas B. Colp** and **James P. March,** each with many years experience in Alaskan mining.

N. B. Sommer has been appointed manager of American Cyanamid Co.'s explosives and mining chemicals department, and **George C. Holton** has been named assistant to the general manager. Dr. Sommer was formerly assistant to the executive vice president. Mr. Holton has been sales manager and department manager.

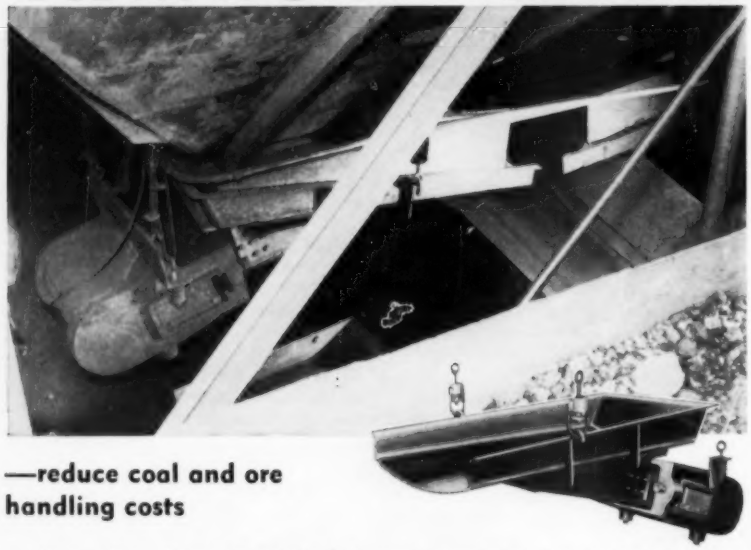
DeWitt Nelson has been reappointed director of the California Dept. of Natural Resources, of which the Div. of Mines is a part. He was chief of the Div. of Forestry before his appointment to this position five years ago.

Joseph R. Gross, formerly pit turn foreman at Jones & Laughlin's Hill Annex iron mine, has been appointed general mine foreman. He succeeds A. C. Seaberg who has become superintendent of the Lind-Greenway mine.

Houston N. Clark has been promoted to the position of assistant to the president, Potash Co. of America.

SYNTRON Vibra-Flow

VIBRATORY FEEDERS



—reduce coal and ore handling costs

—by providing efficient, dependable high capacity controlled flow feeding of coal and ores—fine slack, egg, lump or run-of-mine to conveyor belts, screens, crushers and other process equipment.

SYNTRON Vibratory Feeders offer dependability and low maintenance—simplicity of design, electromagnetic drive eliminates gears, belts, bearings or motors to assure low operation costs. Instantaneous control of flow (manual or automatic) for smooth, even material flow. Compact and durable—easily integrated into continuous process operations.

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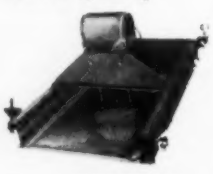


VIBRATORY SCREENS

He had been general superintendent of the company's Dumas and Carlsbad operations. **Raymond R. Knill** will become superintendent of these two plants. **David Rice** will assume Mr. Knill's former position of mine superintendent at Carlsbad.

J. M. MARINCEL

H. A. SMITH

Homer A. Smith was appointed assistant manager, Chemical Distributor Operations, for the Minerals and Chemicals Corp. of America in Menlo Park, N. J.

Joseph M. Marincel has been transferred to Antofagasta, Chile, as shift metallurgist for Andes Copper Mining Co., subsidiary of The Anaconda Co. He will be working at the concentrator of the new El Salvador project. He had been with Anaconda in Montana.

Gordon W. Rowand has been named operations manager of the Spokane office, Western Machinery Co. He had been sales manager for Link-Belt Speeder Corp. of Cedar Rapids, Iowa.

Gerould A. Sabin was made *Advertising Man of the Year* in Denver recently. Mr. Sabin is advertising director of the Colorado Fuel and Iron Corp. and was awarded the citation for "ethical performance of advertising" during his career.

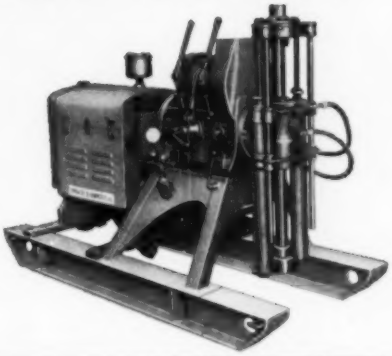
Joel Hunter, president of the Crucible Steel Co. of America, Pittsburgh, has been named to the board of directors of Allis-Chalmers Manufacturing Co., Milwaukee. **Beauchamp E. Smith** has been elected vice president. He is general manager, Hydraulic Div., of the York, Pa., Works, for Allis-Chalmers.

James J. Thompson has been appointed sales manager, TechFab Inc., Nutley, N. J. He will be responsible for supervising the national sales organization.

Paul E. Patten, salesman in Atlas Powder Co.'s Knoxville, Tenn., explosives sales district, has been appointed staff assistant in the construction industry section of the explosives division. His headquarters will remain in Nashville, Tenn.

Leland P. Clemens has been appointed Cleveland District Manager of the Johns-Manville Celite Div., to succeed **R. J. Amberg** who has been transferred to the company's New York office where he will direct cement additives sales.

"THIS IS THE BEST MACHINE FOR MOST CORE DRILLING JOBS"



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We've heard this phrase over and over again from our many customers. They know that it is unsurpassed for foundation investigation, mineral exploration, and grout hole drilling.

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- **STABILITY** — Wider, longer skids and a sturdy steel frame make it very difficult to tip even when moving in mountainous terrain.
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- **MOBILITY** — The 40-CL has a built-in set of sheaves to facilitate movement under its own power. In addition a low-bed trailer is available that permits the use of the rig directly from the trailer mounting in locations where the terrain permits.
- **QUALITY** — Careful machining and time-tested inspection methods substantially increase the trouble-free drill life.

If you want a machine for truck mounting, ask about our 40-C TRUCK-MOUNT. When you want an "all-round" core drill machine, remember that the 40-C and 40-CL Core Drills are just the machines for you.

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personals

continued

Jeremiah J. O'Driscoll, Jr., has been appointed safety engineer for Atlas Powder Co.'s explosives division. He came to Atlas from Catalyst Research Corp., Baltimore.

John R. Burkett will direct commercial operations of the explosives and mining chemicals department, American Cyanamid Co., in his new position as general sales manager. **E. C. Farrar** has been named eastern regional manager and **O. R. Brown** western regional manager of the firm.

Fritz C. Hyde, Jr., has been named assistant general sales manager of Revere Copper and Brass Inc. **Harold F. Relyea** succeeds Mr. Hyde as manager of New York district sales.

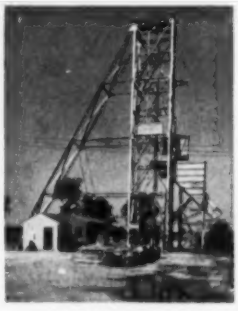
James McNitt joined the staff of the California Div. of Mines in San Francisco as a mining geologist.

John W. Jamar is special representative for the mining machinery division of Lake Shore Inc. He has been promoted from the service and supply division.

Norvert F. Koepel (left), vice president of Anaconda's subsidiaries Chile Exploration Co. and Andes Copper Mining Co., was honored by the Republic of Chile. The Order of Bernardo O'Higgins in the Rank of Knight Commander was presented to him by Walter Müller, Chile's new ambassador to the U. S. The award is for service to Chile.

Lew Adamec, mining engineer with experience in South America and Mexico, left New York in January for the post of general manager of Afra mines, near Melilla, Morocco.

Chester H. Steele, vice president of Western Operations, The Anaconda Co., Butte, Mont., has been named chairman of the program committee for the 1959 Metal Mining and Industrial Minerals Convention of the American Mining Congress to be held in Denver next September. Other committee chairmen are: **Gerould A. Sabin,** publicity; **J. Price Briscoe,** in charge of field trips; **Ben C. Essig,** welcoming committee; and **Mrs. W. T. Ahlborg,** head of the ladies committee.



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CRITERIA

1) *Usefulness to man and nation (public welfare).*
2) *Natural difficulties overcome.*
3) *Size—productivity.*
4) *Life of the mine.*
5) *Solution of unique engineering problems.*

Selections: .....

What are the reasons for your selections? .....

.....

.....

.....

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MINING ENGINEERING
29 West 39th Street
New York 18, N. Y.

W. P. Shoff has resigned as president of Pittsburgh and Fairmont Coal Co., to be succeeded by **Thomas E. Pease,** who has been his assistant.

Inland Steel Co. personnel changes include: **Joseph L. Block,** formerly president and chief executive officer, who will become chairman; **Philip D. Block, Jr.,** former senior vice president in charge of raw materials, who will be vice chairman; **John F. Smith, Jr.,** who has been elected president; and **Hjalmar W. Johnson** who is vice president in charge of steel manufacturing.

H. R. Gault has been appointed head of the department of geology at Lehigh University to succeed Bradford Willard who will retire in June.

Robert C. Hills has been elected president of the Freeport Nickel Co. He is also executive vice president and director of Freeport Sulphur Co. **Charles J. Brown** was elected vice president-sales of the nickel subsidiary. He had been sales manager.

Joy Manufacturing Co. announced new appointments including: **A. W. Calder, previously** manager of the continuous miner and loader department, now director of engineering; **John Merck,** appointed manager of engineering at Joy's Franklin, Pa., plants; and chief engineers for coal machinery product lines, **T. B. Bodimer**, **K. E. McElhattan, C. W. Fitzgerald,** and **C. P. Baldwin.**

Stanley H. Ward is now on the staff of the University of California, Dept. of Mineral Technology, in Berkeley. His business address for his consulting practice is: Secretarial Suite, King Edward Sheraton Hotel, Toronto.

NOTE

AIME has been unable to contact the following members. Anyone with information about them should contact H. N. Appleton, AIME, 29 W. 39th St., New York 18, N. Y.

Name	Date Elected
Eugene Antz	1899
T. W. T. Atherton	1892
Oswald F. Benwell	1928
Hugo Blumenthal	1928
Seymour K. Bradford	1902
Charles W. Comstock	1900
Carl R. Davis	1899
Frederic A. Delano	1886
Fernand J. Dorion	1896
Alfred Fox, Jr.	1905
N. E. Franklin	1928
Walter W. Kroger	1928
Henry D. Lindsley	1928
E. A. Manners	1901
Gilbert McClurg	1928
James Morris	1898
F. Muller-Schall	1928
Noel Parsons	1928
F. E. Pierce	1914
George L. Ramsay	1928
Jesse W. Reno	1887
George A. Richard	1897
W. E. Richardson	1928
Harry L. Rodgers	1928
Percival M. Shaw, Jr.	1928
Leonard D. Sivyer	1914
Tom R. Starkey	1907
Albert W. Taylor	1900
George L. Walker	1928

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fully automatic bag-type

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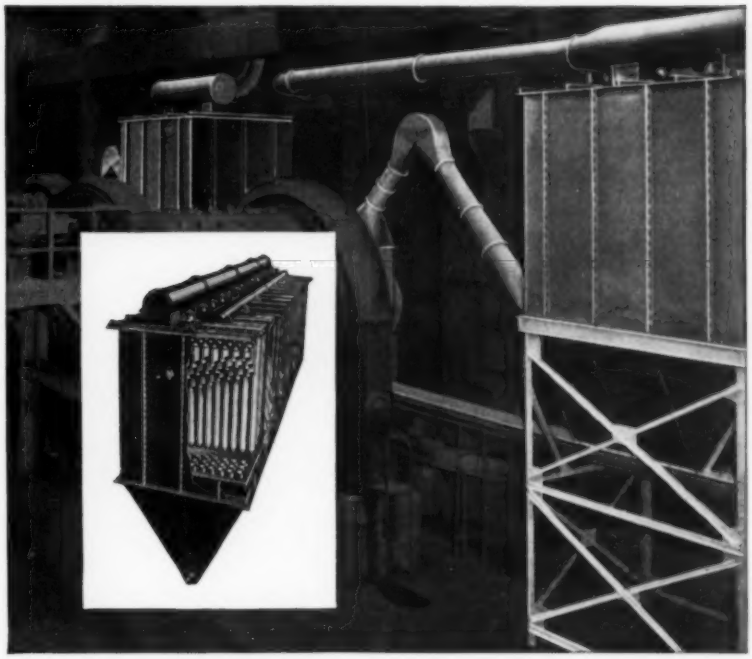

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Obituaries

Cornelius B. Lakenan

Excerpts from an Appreciation
by Shirley Houghton, published
in the *Zeta Psi Circle*

Cornelius B. Lakenan (Legion of Honor Member 1900) died on Jan. 19, 1959, at the age of 91. He was indeed one of the best educated and informed men of present times, and hours of talk and companionship with him were most enlightening. He was born in Grass Valley, Calif., in 1868. It was natural, due to his home environment, and having worked in his father's Lakenan Iron Works on the designing of mining equipment, that he took mining engineering when he went to the University of California. Upon graduation with honors in 1890, he continued in chemical, geological, and mining study at the University of Berlin and the University at Zurich.

Upon his return to America, he spent a short time at Grass Valley in his father's Iron Works where he invented a pump for de-watering deep mine shafts which was built and installed in the North Star Mine at Grass Valley and which was still operating the water control up to the time in recent years when $35 per ounce for gold became too low for profitable operation of the mine.

Following this engagement, he went with the Union Iron Works of San Francisco, in the designing department, in connection with the construction of the U. S. Battleship Oregon. In 1900 the Guggenheim Brothers undertook the financing of a prospect called the Nevada Consolidated Copper Mines. The Guggenheims asked for recommendations for an outstanding mining engineer to take charge of the development of this property with its total investment of $26 million. Cornelius B. Lakenan was recommended and became general manager, a position he held for 26 years, up to his retirement.

He took charge of the property, including two townsites well known today in the state of Nevada as the town of Ely and the town of McGill, located at the mine site and smelter site, respectively. He was often sent on mining investigations for his "bosses", the Guggenheims. One trip to Africa, to make a report on the Rhodesian Copper prospects, another to South America on mining prospects in Nitrate, etc. A few years following the consolidation of Nevada Consolidated Copper Mines with several other mines into the Kennecott Copper Corp., C. B. Lakenan retired.

Joseph A. Bancroft (Member 1920) died over a year ago after spending many years in South Africa. Born in 1882 in Nova Scotia, he was educated at Acadia University there, then continued for an M.A. at Yale University and a Ph.D. at McGill University, where he became professor of geology. He was author of numerous geological publications and did considerable consulting work in Canada, the U. S., and South America. He worked for the Anglo American Corp. of South Africa Ltd. in Johannesburg.

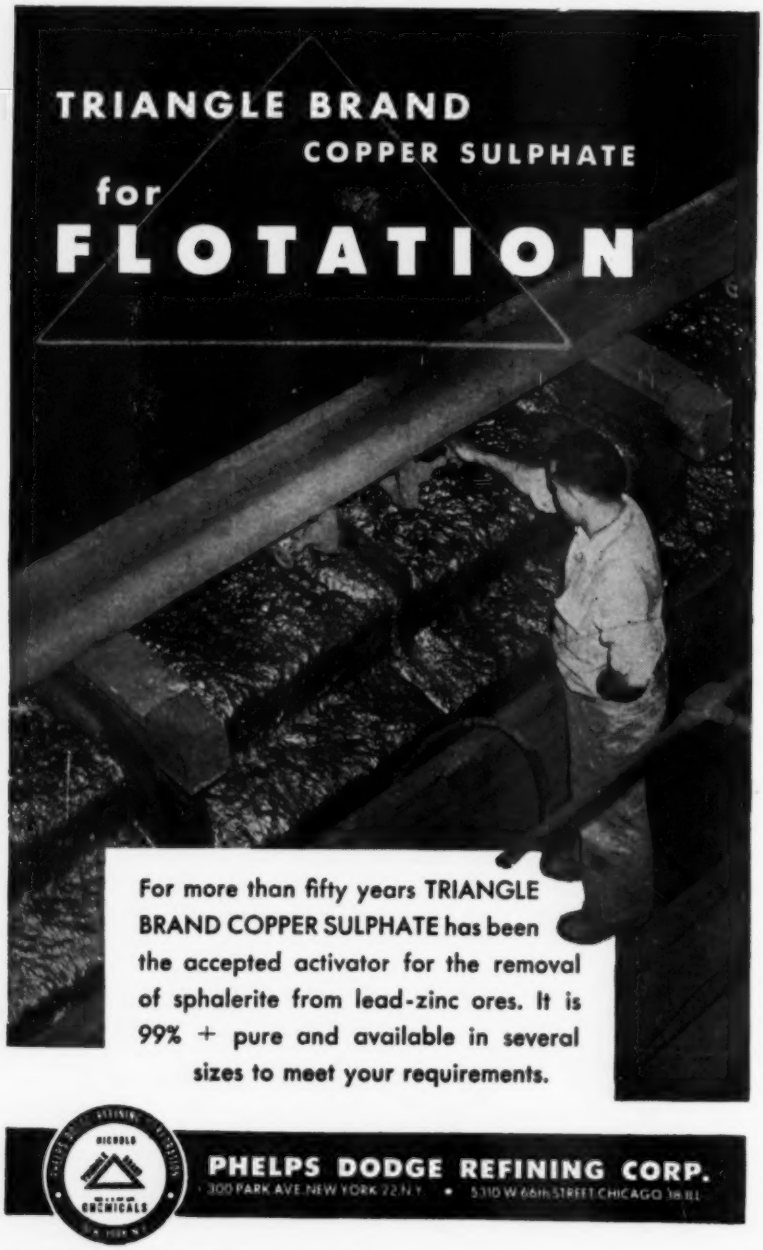
Howard Harris Utley

An Appreciation By
Sim S. Clarke

Howard H. Utley (Legion of Honor Member 1902) age 84, was born in Providence, R. I. on Dec. 1, 1874, and died Feb. 15, 1959, at his home in Baxter Springs, Kan., after long illness.

For 31 years he was a member of The National Lead Co.'s organization, retiring ten years ago after serving for 30 years as manager of the St. Louis Smelting & Refining Co., Div. of National Lead Co.

Mr. Utley graduated from Brown University in 1897 and Colorado School of Mines in 1900, receiving the degree of mining engineer.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After graduating, he was employed by the Colorado Fuel & Iron Co.; later he joined the Speed Coal Co.; at Frankfort, Ky. He also spent some time in Parrall, Mexico, and was also employed in the Leadville Colorado district. He was offered an assignment in either Burma or Baxter Springs by The National, and chose Baxter.

In 1918 he joined the staff of The National Lead Co. at Florence, Colo., and a year later was transferred to Baxter Springs, Kan., where he served until his retirement.

At Denver, in June 1905 he was married to Marjorie Carpenter of Boston, who survives him.

Mr. Utley was active in civic and engineering society work and practiced as a consulting engineer for a few years after his retirement. Howard was a man of integrity, conscientious in his obligations to his company, his employes, and his community. He will be greatly missed by his many friends.

An Appreciation By
Duane M. Kline

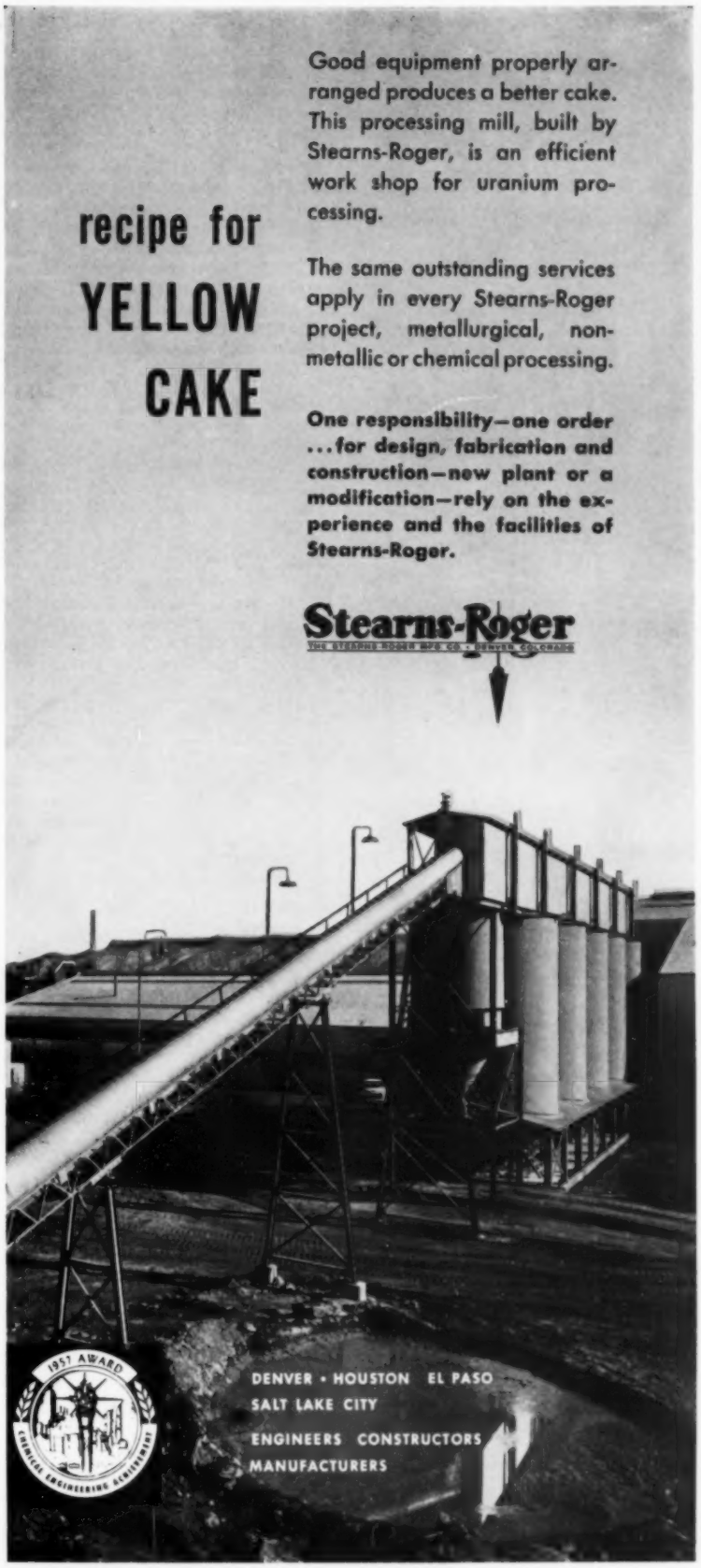
The Mining Fraternity lost one of its oldest and most respected members in Howard H. Utley, who passed away at his Baxter Springs, Kan., residence at 2:10 am Sunday morning, Feb. 15, 1959. Mr. Utley's health had been failing for a long period of time.

Mr. Utley was born Dec. 1, 1874, in Providence, R. I., making him 84 years old at the time of his death. He attended Boston College and later Colorado School of Mines where he received his Engineer of Mines degree.

Mr. Utley worked at his profession in Carbondale, Colo.; Mexico; Kentucky; and at Florence, Colo., where he was general manager, River Smelting and Refining Co., producing a zinc pigment paint. This operation was purchased by The National Lead Co. After the closing of the Florence plant, Mr. Utley moved to Baxter Springs to manage the St. Louis Smelting and Refining Co.'s operations in the Tri-State, a position he held at the time of his retirement. He had been in the Tri-State district for a period of 30 years.

Mr. Utley belong to the Legion of Honor, AIME, having been a member 57 years. He was also a member of the Mining Club, New York.

Leland C. Ball (Member 1936) passed away on June 23, 1958. Born in Minneapolis in 1891, he attended the Michigan College of Mines. As assistant engineer on survey corps underground for the Transit Ellsworth Collieries Co. in Pennsylvania, he also organized the Mine Rescue Corps. Then he spent seven years in Chile in charge of warehouse construction for U. S. Steel Products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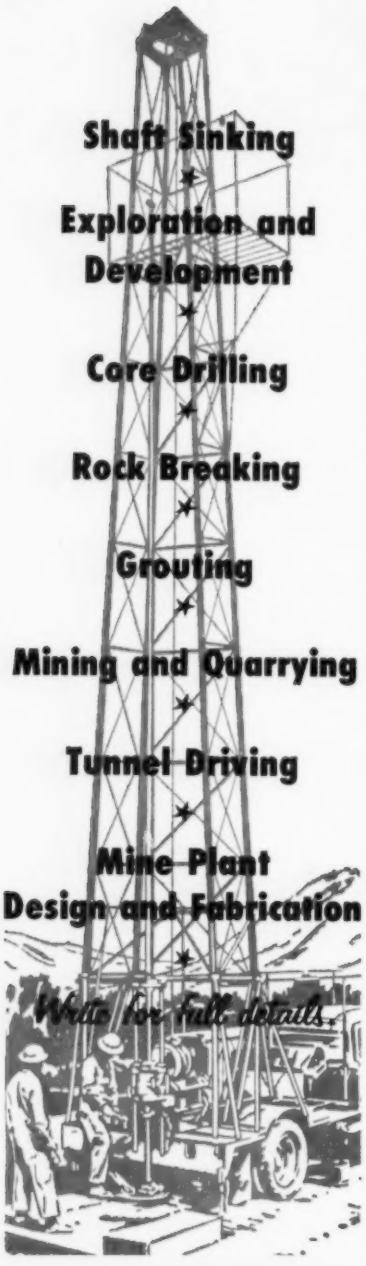

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Reno, Nevada — FAirview 9-0732
Spokane, Washington — WAlnut 4-2614
Alaska — Contact Salt Lake City Office

Co. He returned to New York in 1920 as an export manager, for three years, then settled again in Chile. In 1929 he became president of The Ault & Wiborg Argentine Co. in Buenos Aires and in 1936 he moved again to Chicago.

Lawrence W. Allen (Member 1944) died in July 1958. He was born in Johannesburg, South Africa, in 1908 and attended university in England, completing the course for B. Eng. He began his engineering career at the Dervent Valley Water Board in England. He was an assistant engineer for several firms before establishing the partnership of Allen & Ramsay. In 1937 he was back in Johannesburg working for Crown Mines Ltd. He became chief underground surveyor for Nchanga Consolidated Copper Mines Ltd. in Northern Rhodesia and in 1942 became technical assistant to the manager. He was working for this firm at the time of his death.

Jesse T. Boyd (Member 1914) died Jan. 3, 1959, after a prolonged illness. He was born in Pennsylvania in 1883 and attended the Colorado School of Mines. In 1908 he was resident engineer for Camp Bird Mines Ltd. in Ouray, Colo. He also did mine examination work for New Jersey Zinc Co. at this time and located the bulk of uranium and vanadium claims for Pittsburgh people in Colorado. He became manager for North American Lead Co. in Ontario in 1912. As field engineer for Empire and New Jersey Zinc Cos. he recommended purchases, then took charge of properties which became leading zinc mines of the west.

Joseph E. Kennedy (Member 1911), chairman of the board of the Kennedy-Van Saun Manufacturing & Engineering Co., died at the age of 95 on Jan. 9, 1959. Mr. Kennedy had founded the company and built its manufacturing plant at Danville, Pa., in 1916. He is the holder of several hundred patents. Born in Pennsylvania, he gained thirty years experience in Canada, Mexico, and the U. S. by the time he joined AIME.

J. Francis Linthicum (Member 1917) died on Nov. 17, 1958. He had received an A.B. from St. Johns College in 1902 and began his career as a chemist in his home state of Maryland. After several positions as assistant chemist he became chief chemist for The Spanish American Iron Co. in Cuba. In 1920 he was works manager for Bauxite Products Co. in St. Louis. He worked for many years for Aluminum Co. of America in Cleveland and Pittsburgh, where he became manager of fluorspar, chemical, and byproduct sales. Later in his career he was with American Lumber and Treating Co. in Chicago.

Necrology

Date Elected	Name	Date of Death
1937	Edgar M. Barker	Mar. 19, 1959
1947	Marc E. De B. Remy	January 1959
1920	David Donoghue	Sept. 15, 1958
1935	P. E. Green	1958
1954	L. M. Hartvigsen	Unknown
1952	Robert E. Loeck	January 1959
1955	H. Leslie Parker	Unknown
1945	T. W. Saylor	Apr. 7, 1959
1953	Harry B. Schramm	May 1, 1958
1945	John C. Steward	Feb. 4, 1959
1955	Stephen Szeli	Unknown
1893	Arthur L. Tuttle	Unknown
	Legion of Honor	
1957	W. E. Walker	Unknown

Lee Olds Kellogg

An Appreciation By
M. D. Banghart

Lee Olds Kellogg (Member 1913) passed away on Dec. 2, 1958, in Carmel, Calif., at the age of 77. Lee was born in Rochester, Minn., on March 7, 1881. He was graduated from the University of Minnesota in 1902, the president of his class and a member of Phi Beta Kappa. He secured his Master's degree in mining engineering from the Columbia University School of Mines in 1906.

Lee served in various capacities as a mining engineer in western U. S. and Mexico before joining the editorial staff of the *Engineering and Mining Journal* in New York. In 1916 he accepted the position as general superintendent of the gold mining operations of the South American Development Co., Portovelo, Ecuador, a position which he held until his retirement in 1928.

He was married to Miss Alice Lovell in 1907. Lee and Alice Kellogg celebrated their 50th wedding anniversary in 1957. In addition to his wife, he left a son, John Lovell Kellogg of Carmel, two daughters, Mrs. Ruth Woodyard of Berkeley, Calif., and Mrs. Mary Chapman of Fullerton, Calif.

His warm and friendly personality, even temper and patience were greatly appreciated by his associates at Portovelo. In particular, I am sure that every young engineer that worked for Lee Kellogg owes him a debt of gratitude for the sound advice that he gave them when the occasion demanded. I recall one such piece of advice—"Anyone working in another man's country should consider it a privilege, and when he no longer feels that way, he should go home.'"

Lemuel R. Jenkins (Member 1915) died Dec. 25, 1957. He attended Harvard College and graduated in 1907 with an S.B. degree, having been born in Massachusetts in 1882. He gained experience in Newfoundland where he was superintendent of the York Harbor mine. He later became assistant superintendent at the Mammoth mine in Kennett, Calif., where he had been a miner early in his career.

Albert R. Eckel (Member 1958), president of Commercialores Inc. in Clover, S. C., passed away on Dec. 4, 1958. He had been born in Albert Lea, Minn., in 1901 and attended Rensselaer Polytechnic Inst. In 1920 he was with the engineering corps of the New York Central Railroad and in 1953 became chief engineer for Eastern Rock Products Inc. For 22 years he was eastern manager of Chilton Co. which publishes *Iron Age* and *Automotive Industries*. He has been president of Commercialores Inc. for nine years.

Henry L. Hollis (Legion of Honor Member 1885) died Nov. 20, 1958. A native of Massachusetts, he received an E.M. degree from Columbia University in 1885. He gained mining experience in Mexico and British Columbia with various firms, acting as managing director. For many years he lived in Chicago.

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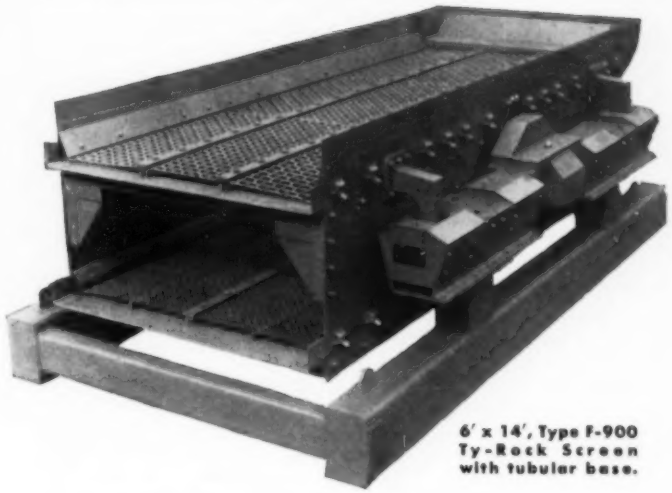

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Let's take a look at the facts about grinding mills

Comminution is a subject that is by no means new and perhaps more tons have been ground in discussion than in practice. But still it must be considered an art, not an exact science. Marcy realizes this as well as you do. However, we at Mine and Smelter take this art very seriously and apply as scientific an approach as is possible in recommending type, size and quality of mills for your requirements.

These Marcy Mills, whether they be rod mills with a high or low discharge level, or ball mills with Marcy grate design or the overflow type, are all "Custom Engineered" for *your* particular problem. There has never been a formula, capacity table, or performance curve developed which can be used to accurately select a mill for a specific job. A background of experience, applied with sound judgment, is essential for a successful solution of the problem. . . you cannot just select a size from "standard" models.

This engineering service, with final mill design based on hundreds of *field-proven* Marcy designs, carries no penalty in price. Of the *field-proven* features incorporated in the design of *your* Marcy Mill, many may be of recent development, some as old as grinding itself . . . but, the most important ingredient in the design of *your* mill is the extensive grinding experience by Marcy, which results in a design incorporating the correct combination of these field-proven features for *your* job . . . an ingredient which is responsible for Marcy's leadership in grinding.

What is really new in mill design? A talk with Marcy engineers will provide you with an insight on this subject, including interesting facts about the past, present and future of grinding. We at Mine and Smelter favor continual progress, but we respect history as a teacher . . . a most worthy instructor for guiding future progress.

"Custom Engineering" *your* Marcy Mill is our favorite subject . . . it could be yours, just contact . . .

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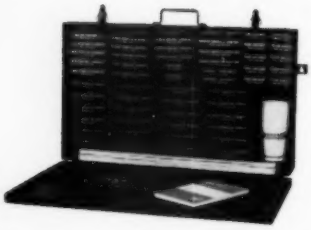
M-S-A® Type D ALL-WEATHER FIRST AID KITS

When emergencies call for first aid, these kits provide all the advantages for quick, complete treatment. Unit packages, easily replaced, are arranged for fast selection, contain one or more complete dressings or treatments for each injury. All dressings are sterilized and ready for use. Cellophane package wrappings protect contents. The kits, available in 10, 16, 24, and 36 units, are made of 20-gauge steel, with carrying handle, and mounting brackets. Case is dust and moisture-proof. Ideal for carrying on jeeps, motors or other mechanized equipment. Complete instructions with each kit. Write for details.

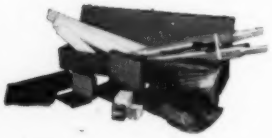


M-S-A MINER'S FIRST AID CABINET

Contains complete assortment of first aid material and supplies. Ideal for mine hospital or dressing stations. Contents conform to U. S. Bureau of Mines recommendations.

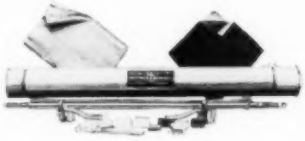
M-S-A FOILLE BURN KIT

Contains four 10-ounce Foille Aerosol Sprays, easy-to-use Type D first aid dressings and accessories. Stored in All-Weather steel case. Permits fast effective burn treatment.



M-S-A EMERGENCY FIRST AID OUTFIT

Ideal for storage underground where a compact unit is needed. Contents selected to meet practically every emergency. Includes two first aid kits, blankets, splints, Redi-Heat Blocks, stretchers. Sturdy steel case.



M-S-A STANDARD STRETCHER OUTFIT

Complete assortment of first aid dressings and supplies arranged in a strong dust-proof canister. Contains stretcher, blankets, first aid materials, splints. Designed for first aid rooms, dressing stations.

MSA . . . headquarters for First Aid Equipment

Above are a few of the many first aid supplies and treatments available from M-S-A. This material is the result of years of experience in serving the mining industries' requirements.

Our knowledge of emergency needs has developed the design and contents of our first aid line.

You will find complete information in our Mining Catalog•••••30 pages are devoted to illustrations and detailed information on these and many other first aid supplies. We will be happy to send you a copy upon request.

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